A TEXTBOOK OF INVERTEBRATES

Dedicated to

Our Teacher

PROF. A.K. PANDEY

Who Left us so Early

PREFACE

The present title is a comprehensive uptodate textbook. This is an indispensable text meeting complete requirements of undergraduate and postgraduate students of Zoology. It has been designed to approach the morphology, anatomy, physiology and development of selected type in a very simple and lucid style. According to the scheme of treatment the important animal types of each phylum have been dealt with first, and efforts have been made to present their elaborate and uptodate account. In the description of animal types special emphasis has been laid on the functioning of organs. General characters and classification and brief description of other important types of the phylum have also been dealt with complete authentic and uptodate account. Separate chapters on topics of significance and general interest pertaining to the phylum have also been added to make the treatment more elaborate. Adaptations of animal types have been discussed in detail to reveal their relation with the environment.

It has been the constant endeavour of the authors to furnish maximum substance, keeping in view the limitations of size of the volume. Efforts have been made to condense, the matter as far as practicable. The book features both a text and a laboratory guide. It is hoped that this book will not only meet the requirement of Indian students but will also be useful as a guideline to the teachers in their teaching.

There can be no claim to originality except in the manner of treatment and much of the information has been obtained from the books and scientific journal available in different libraries.

The authors express their thanks to all their friends and colleagues for assisting us in various ways.

The authors are deeply grateful to Dr. A.B. Saxena, Dr. K.S. Rao of School of Studies in Zoolozy, Vikram University Ujjain, for their competent advice, constant helpfulness and good spirit during the writing of this book.

Though, the authors have taken special care to present a current account, yet they are fully aware about their limitations and the readers may come across the mistakes of various types. For all types of mistakes they extend their due apology.

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Authors

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CHARACTERS & CLASSIFICATION OF PROTOZOA

The protozoa are a heterogenous assemblage of some 50,000 *acellular* or single-cell organisms possessing typical (eukaryote) membrane bound cellular organelles. Being the simplest in structure, protozoa are regarded most primitive or first animals (Gr. *protos* - first; zoon = animal) of Nature. The acellular level of organization is the only characteristic by which the protozoa as a whole can be described; in all other respects they display extreme display. They exhibit all types of symmetry, a great range of complexity, and adaptations for all types of environmental conditions. Protozoa were first seen by *Leeuwenhoek* (1677). The other pioneers, in the field of Protozoology, are *Joblot* (1718), *Trembley* (1744), *Linnaeus (1758)*, *Muller* (1773), *Dujardin* (1845), *Haeckel* (1862), *Pasteur* (1870), *Butschli* (1881), *Ronald Ross* (1898), etc. Term Protozoa was coined by *Goldfuss* (1817). *Grassi* (1952), *Hall* (1953), *Kudo* (1954), *Pitelka* (1953-59), *Allen* (1962) etc. have made their valuable contribution to the protozoology in present century.

GENERAL CHARACTERS

(1) Protozoa occur wherever moisture is present-in the sea (marine) in all types of fresh water, and in the soil. There are commensal, mutualistic, and many parasitic species. In fact the sporozoans are entirely parasitic.

(2) All though most protozoa occur as solitary individuals, there are numerous colonial forms. Some colonial forms, such as *Volvox*, attain such a degree of cellular interdependence that they approach a true multicellular level of structure. Both solitary and colonial species may be either free-moving or sessile.

(3) The great majority of protozoa are microscopic. *Anaplasma*, a blood parasite, is so smalls that it occupies only 1\6 to 1\10th of a red blood corpuscles. At the other hand, the freshwater ciliate, *Spirostomum*, may reach a length of 3.0 mm. and be seen with the naked eye. A fossil foraminiferan, *Nummulites*, was 19 cm. across, probably the largest size that has been attained by any protozoan.

(4) Body symmetry nonradial, spherical or bilateral.

(5) The body is either naked or covered by *pellicle*. Sometimes an exoskeleton is also present.

(6) The shape of body is usually constant but in some cases it is unstable and in others it may change with the environment or age.

(7) Their locomotory organelles are finger-line *pseudopodia*, *flagella*, *cilia* or absent as in sporozoans.

(8) Nutrition may be *holozoic* (animal like), *holophytic* (plant-like), *saprozoic* or *parasitic*. The organelles of ingestion and egestion may be present or absent. Digestion occurs intracellularly inside the food vacuoles in most cases.

(9) No specific respiratory and excretory organs are present. Both are carried through general body surface by *diffusion* Excretion sometimes carried with the help of contractile vacuole.

(10) In fresh water protozoa excess water is usually eleminated by a contractile vacuole. Thus these are mainly osmoregulatory in function.

(11) Asexual reproduction by *binary fission*, *multiple fission* or *budding* occurs at some time in the life history of almost all protozoa. Meiosis, gamete formation, and fertilization have been observed in many species, but the nature of these events and their occurrence in the life cycle of the organism is highly variable. Encystment is common.

(12) Life-history is often complicated in some cases with alternation of asexual and sexual phases.

(13) Their body is not distinctly differentiated into *somatoplasm* and *germplasm*, hence natural death does not take place in them.

Special characters

(1) Their acellular body regulates all the life activities thus there is no physiological division of labour. The division of labour is restricted to the organelles which are intracellular or subcellular structures.

(2) The animals give their respond to various stimuli. This gives an indication of the beginning of the nervous system of metazoans.

(3) The microconjugants and macroconjugants in the conjugation of *Vorticella* indicate the beginning of *sexual dimorphism*.

CLASSIFICATION OF PHYLUM-PROTOZOA

There is disagreement among Protozoologits on the ways of classifying Protozoa. Modern workers like *Kazloff* (1972) and *Robert D. Barnes* (1980) tend to believe that this group includes more than one unicellular phyla. *Barnes* (1980) raised the four major groups viz. *Mastigophora, Sarcodina, Sporozoa* and *Ciliophora* to the rank of independent phylum. Here we are following the classification given by "Committee on Taxonomy and Taxonomic Problems of the Protozoologists" (*Honiberg et al.*, 1964).

According to *Honiberg et al.*, Protozoa have been classified into four subphyla.

Subphylum	I	SARCOMASTIGOPHORA
Subphylum	II	SPOROZOA
Subphylum	III	CNIDOSPORA
Subphylum	IV	CILIOPHORA

SUBPHYLUM .I SARCOMASTIGOPHORA

(1) Organelles of locomotion are pseudopodia or flagella.

(2) Nucleus monomorphic (single type).

(3) Nutrition holozoic or holophytic.

(4) Asexual reproduction by binary or multiple fission.

(5) Sexual reproduction by syngamy; no spore formation.

This subphylum is divided into three super classes:

SUPER CLASS A - MASTIGOPHORA

1. Simple and primitive. Body with firm pellicle.
2. One to many flagella for locomotion.
3. Asexual reproduction by binary, more or less sometogenic, fission.
4. Autotrophic or heterotrophic or both.

Class-I, Phytomastigophora

1. Mostly free-living.
2. Plant-like flagellates with or without chromoplasts.
3. Usually one or two flagella, the nucleus vesicular.
4. Reserve food as starch or paramylon.

Order. 1. Chrysomonadia

1. Small flegellate with yellow or brown chromoplast.
2. One to three flagella are present.
3. Gullet absent; stigma present.
4. Nutrition holophytic. Starch absent but leucosin and fat droplets are present.
5. Silicious cysts. Marine or fresh water.

   Examples. *Chromulina, Synura, Ochromonas, Uroglena* etc.

Order. 2. Coccolithophorida

1. Tiny marine flagellates covered by calcareous platelets-coccoliths.
2. Two flagella and yellow to brown chromoplast.
3. No endogenous silicious cysts.

   Examples: *Coccolithus, Rhabdosphaera.*

Order 3- Heterochlorida

1. Two unequal flagella and yellow-green chromoplasts.
2. Silicious cysts.

   Examples: *Heterochloris, Myxochloris.*

Order-4-Cryptomonadida

1. Compressed with a rigid pellicle.
2. Gullet reaches upto the middle of the body.
3. They have two unequal flagella. Green, yellow, brown or colourless chromatophores which form starch.
4. Stigma often present.
5. Marine or fresh water

   Examples: *Chilomonas, Cryptomonas.*

Order-5-Dinoflagellata

1. Small and planktonic. Body naked or with a thick pellicle or cellulose theca.
2. Two flagella, one lying transversely and the other pointing backwards.
3. Chromatophores are green, yellow, or brown.
4. Reserve food is starch or oil.
5. There are complex vacuoles which are not contractile.
6. Some are bioluminescent.
7. Mostly marine, some are parasitic.

   Examples: *Noctiluca, Ceratium; Oodinium, Gonyaulax.*

Order-6-Chloromonadida

1. Small, with a delicate and dorso-ventrally flatenned pellicle.

2. Two flagella, one trailing.
3. Chromatophores green and numerous.
4. Reserve food is oil.
5. Stigma absent; complex.
6. Contractile vacuole present.
7. Largely freshwater.

   Examples: *Gonyostomum, Vacularia.*

Order-7-Euglenida

1. Large with a thick and firm pellicle.
2. Anterior end with gullet leading into reservoir.
3. One or two flagella arising from an anterior recess.
4. Stigma present in coloured form.
5. Chromatophores green and numerous sometimes colourless.
6. Reserve food is paramylon and oil.
7. Mostly fresh water.

   Examples: *Euglena, Phacus, Peranema, Rhabdomonas.*

Order-8. Volvocida

1. Small with rigid cellulose covering theca.
2. Gullet absent.
3. Flagella usually two sometimes more.
4. Body with green, usually single cup-shaped chromoplast.
5. Reserve food is starch and oil.
6. Stigma present.
7. Mostly fresh water forms. Many colonial species.

   Examples: *Volvox, Chlamydomonas, Polystomella, Gonium, Pandori*

Class-2 Zoomastigophora (Zoomastigina)

1. Flagellates with neither chromoplasts nor leucoplasts.
2. One to many flagella, in most cases with basal granule complex.
3. Reserve food glycogen.
4. Sexual stage unknown.
5. Many commensals, symbionts and parasites.

Order-1. Choano flagellida.

1. Fresh water flagellates, with a single flagellum surrounded by a collar.
2. Sessile, sometimes stalked, sometimes with lorica.

3. Solitary or colonial.

   Examples: *Codosiga, Salpingoeca, Proterospongia.*

Order-2. Bicosoecida

1. Largely fresh water flagellate encased within a lorica.
2. Two flagella, one free, the other attaching posterior end of body or shell.

   Examples: *Bicosoeca, Poteriodendron.*

Order-3. Rhizomastigida

1. Small and amoeboid forms.
2. Flagella one or more upto four.
3. Locomotion by pseudopodia and flagella.
4. Chiefly freshwater.

   Examples: *Mastigamoeba, Dimorpha*

Order-4. Kinetoplastida

1. Small and more or less amoeboid in forms; no gullet.
2. Flagella basically one, but up to four.
3. Mostly parasitic forms, some are freshwater. Freshwater forms sessile, sometimes stalked.

   Examples: *Bodo, Trypanosoma, Leishmania.*

Order. 5. Retortamonadida

1. Gut parasites of insects or vertebrates.
2. One to four flagella. One flagellum associated with ventrally located cytostome.

   Example: *Chilomastix.*

Order-6. Diplomonadida

1. Small with a pellicle and often with a cytostome.
2. Bilaterally symmetrical flagellates, with two nuclei, each nucleus associated with four flagella.
3. Mostly parasitic.

   Examples: *Giardia, Hexamita.*

Order-7. Oxymonadida

1. Symbiotic flagellates having one to many nuclei. Each nucleus associated with four flagella, some of which are turned posteriorly and adhere to body surface.

   Examples: *Oxymonas, Pyrsonympha.*

Order-8. Trichomonadida

1. Four to six flagella, one of which is trailing.
2. Parasites in genital passage.

   Example: *Trichomonas.*

Order-9. Hypermastigida

1. Highly specialized forms with numerous flagella.
2. Kinetosomes arranged in a circle, plate or longitudinal or spiral rows.
3. Uninucleate or multinucleate but never binucleate.
4. Food ingestion by pseudopodia.
5. Symbionts in the guts of termites, cockroaches and wood roaches.

   Examples: *Lophomonas, Trichonympha, Barbulanympha.*

SUPER CLASS - B - OPALINATA

1. Body covered by longitudinal, oblique rows of cilia arising from anterior subterminal rows.
2. Cytostome is absent.
3. Two or many monomorphic nuclei.
4. Binary fission generally symmetrogenic.
5. Sexual reproduction involves syngamy with flagellated gametes (anisogamous).
6. Parasitic found in gut of frogs and toads; less commonly in fishes, salamanders and reptiles.

   Examples: *Opalina, Zelleriella.*

SUPER CLASS - C - SARCODINA

1. Protozoa with pseudopodia as feeding and locomotor organelles.
2. Flagella, when present, only in development.
3. Asexual reproduction by binary fission.
4. Mostly solitary and free-living, some parasitic and colonial.
5. Skeletons of various forms and composition characteristic of some groups.

Class - 1- Rhizopoda

1. The locomotory organelles are *lobopodia, filopodia* or *reticulopodia*, but never *axopodia.*
2. Generally creeping forms.

Sub.-Class-(i) Lobosa

1. Pseudopodia usually lobopodia.

Order-1. Amoebida

1. Body is naked without any exoskeleton.
2. Typically uninucleate, ectoplasm and endoplasm are clearly differentiated.
3. Nucleus with honeycomb lattice.
4. Largely fresh water, some marine; many parasites.

   Examples: *Amoeba, Entamoeba, Pelomyxa.*

Order-2. Arcellinida

1. Body enclosed in a shell or test with an aperture through which the pseudopodia protrude.

2. They are free living mostly fresh water.

   Examples: *Arcella, Difflugia, Euglypha.*

Sub (ii) Granuloreticulosia

1. They have fine granular reticulopodia

Order-Foramaniferida

1. Chiefly marine species with mostly multi-chambered shells.
2. Shells may be composed of tectin, which may incorporate foreign particles, but most commonly the shells are calcareous.
3. Shells with one or more openings through which reticulopodia emerge. The reticulopodia are fine and branched forming network.
4. Chiefly marine.

   Examples: *Elphidium, Globigerina, Orbulina, Spirillina.*

Sub class (ii) Filosa.

1. Pseudopodia as filopodia, tapering and branching.
2. Body naked with a shall with single aperture.
3. Marine and freshwater.

   Examples: *Allogromia, Gromia*

Sub class (iv) Mycetozola

1. Body large, amoeboid, multinucleate forming plasmodia.
2. Life-cycle complex and has sexual reproduction, usually sporangia are formed which liberate spores.
3. Pseudopodia numerous and blunt.

   Examples: *Arcyria, Plasmodiophora.*

Class-2. Actinopodea

1. The locomotony organelles are delicate *axopodia* with axial filaments.
2. They are primarily sessile or floating forms.
3. Test may be present or absent.
4. Reproduction both asexual and sexual.

Subclass- (i) Radiolaria

1. Body comparatively larger; central capsule is perforated by one or many pores.
2. Siliceous skeleton.
3. Axopodia or sometimes reticulopodia or filopodia.
4. Exclusively marine.

The radiolarians can be divided into two groups or classes: The Polycystina has a central capsule with evenly distributed pores or a pore field. The Phaeodaria have three pore fields and the organic nature of the capsule wall is different from that of Polycystina.

Examples: *Collozoum, Acanthometra, Aulocantha.*

Subclass (ii) Acantharia

1. Imperforate, nonchitinoid central capsule without pores.
2. Anisotropic skeleton of strontium sulphate.
3. Axopodia present. Marine.

   Example: *Acanthometra.*

Subclass (iii) Heliozoida

1. Spherical animal without central capsule commonly called *Sun-animalcules.*
2. Axopodia radiating.
3. Body cytoplasm is differentiated into outer vacuolated ectoplasm and inner dense endoplasm.
4. Skeleton absent (naked); if present, it is made up of siliceous scales and spines.
5. Primarily in fresh water.

   Examples: *Actinophrys, Actinosphaerium, Camptonema.*

Subclass (iv) Proteomyxida

1. Largely marine and freshwater parasites of algae and higher plants.
2. Pseudopodia are filopodia and reticulopodia.
3. Reproduction by binary or multiple fission; multiple fission in cyst.

   Examples: *Vampyrella, Pseudospora.*

Class - 3 - Piroplasmea

1. Small, round, rod-shaped or amoeboid.
2. Parasite in red blood corpuscles of vertebrates.
3. Do not produce spores.

   Example: *Babesia*

SUBPHYLUM II SPOROZOA

1. Exclusive endoparasites.
2. The locomotory organelles are absent in adults.
3. Cilia or flagella may be present in gametes.
4. Nutrition saprozoic.
5. Asexual reproduction by multiple fission and sexual by syngamy, followed by spore formation.
6. Sporozoites are infective stage; nucleus is of single type.

Class - 1. Telosporea

1. Pseudopodia are absent and locomotion is by gliding or body flexion.
2. Spores without capsules or filaments, naked or encysted.

3. Adult trophozoites with one nucleus.
4. Reproduction is both asexual and sexual.

Subclass - (i) Gregarinia

1. Mature trophozoites are large and extracellular.
2. Reproduction is sexual with sporogony; spores contains eight sporozoites.
3. These are parasite of gut and body cavity of invertebrates.

   Examples: *Gregarina, Monocystis*

Subclass (ii) Coccidia

1. Mature trophozoites are small and intracellular.
2. Female gametes hologamous.
3. Sporzoites multiply by schizogony in tissue cells.

Order 1. Eucoccida.

1. Asexual and sexual both the phases occur in life-cycle.
2. They are parasite in epithelial and blood cells of invertebrates and vertebrates.

Suborder (a) Eimeriina

1. Macrogametes and microgametes develop independently.
2. Syzygy is absent. Zygote is non-motile.
3. Sporozoites are encased in sporocyst.

   Example: *Eimeria*

Suborder (b) Haemosporina

1. Macrogametes and microgametes develop independently.
2. Syzygy is absent. Zygote (ookinate) motile.
3. Sporozoites are naked.
4. Schizogony in vertebrate host and sporogony in invertebrate hosts.

   Example: *Plasmodium.*

Class -2 - Toxoplasmea

1. Spore formation is absent.
2. Reproduction asexual by binary fission.
3. Cysts are formed which have many naked sporozoites. No flagella or pseudopodia.

   Examples: *Toxoplasma, Sarcocystis.*

Class - 3 - Haplosporea

1. Spores are present.
2. Pseudopodia may be present but flagella absent.

3. Reproduction only by asexual means.
4. Parasites of fish and invertebrates.

   Examples: *Ichthyosporidium*, *Haplosporidium*.

SUBPHYLUM III. CNIDOSPORA

1. Adult trophozoite has many nuclei.
2. Spore formation occurs throughout life.
3. Spores have several cells having one or more polar filaments which are coiled threads and can be shot out.
4. Zygote gives rise to one or more trophozoites without sporogony.

Class-1 Myxosporidea

1. Spores develop from several nuclei and enclosed in two or three valves. Polar capsule present.

Order. 1. Myxosporida

1. Spores are large with a bivalved membrane.
2. Trophozoite amoeboid and not intracellular.
3. Polar capsule 1, 2 or 4 with filaments.

   Example: *Myxidium*

Order - 2 - Actinomyxida

1. Spores large with a trivalved membrane.
2. Polar capsule three, each with a filament.

   Example: *Triactinomyxon*.

Class-2, Microsporidea

1. Spores small, with a univalved membrane.
2. Polar capsule absent or present with 1 or 2 filaments.

   Example: *Nosema*.

SUBPHYCUM-IV CILIOPHORA

1. The ciliates comprise the largest subphylum of Protozoa. Some 8000 species have been described and many groups are still not well known. They are also the most animal like and exhibit a very high level of organelle development.
2. The shape of body is definite. The body wall is a complex living pellicle, containing alveoli, trichocysts and other organelles, in addition to infraciliature.
3. The body surface is covered with uniform cilia which function in locomotion.
4. The cilia around the cytostome region have become specialized as compound ciliary organelles called membranelles and undulating membranes in many ciliates that employ filter feeding.
5. Most of them have two types of nuclei-larger macronucleus and smaller micronucleus.
6. One or more contractile vacuoles are present in fresh water forms.
7. Reproduction asexual by transverse binary fission.

8. Conjugation also takes place with fusion of nuclei.
9. The anal aperture or cytopyge is a permanent aperture.
10. No alternation of generation in the life-cycle.

Class-1 Ciliata

1. Cilia are present during the whole or a part of their life cycle.
2. Mouth or cytostome and cytophanynx are often present.
3. Nutrition is holozoic.
4. Reproduction takes place asexually by binary fission or budding and sexually by conjugation.
5. Mostly free living in fresh water, marine but parasites; colonial and sedentary forms also occur.

Class ciliata is divided into four subclasses:

Sub class-(i) Holotricha.

1. Cilia usually short and uniform, arranged in longitudinal rows all over the body.
2. No adoral spiral of long cilia or membranelles.
3. Buccal ciliature either absent or, if present, usually inconspicuous.

The subclass Holotricha is divided into following orders:

Order 1, Gymnostomatida

1. Chiefly large ciliates with no oral ciliature.
2. Cytostome opens directly to out side.

Examples: *Didinium, Nassula, Coleps.*

Order 2.- Trichostomatida

1. With vestibular but no buccal ciliature.
2. Free living and parasitic forms.

Examples: *Colpoda, Balantidium.*

Order 3 - Chonotrichida

1. Vase-shaped ciliates lacking body cilia.
2. A funnel at the free end of the body bears vestibular cilia.
3. Chiefly marine and ectocommensel on crustaceans.

Examples: *Spirochona, Chilodochona.*

Order - 4 - Apostomatida

1. Body with spirally arranged ciliation.
2. Cytostome mid-ventral.
3. Marine parasite. Life. cycle complex usually involving two hosts, one of which is crustacean.

Example: *Hyalophysa.*

Order - 5 Astomatida

1. Body ciliation uniform.
2. Cytostome absent.
3. Commensals or endoparasites living in the gut and body cavity of oligochaete worms.

   Examples: *Hoplitophrya, Anoplophrya.*

Order - 6. Hymenostomatida.

1. Mouth usually lies on the side of the body at the end of peristome, remains permanently open and leads into cytopharynx.
2. Buccal cavity present with membranes.
3. Small body with uniform cilia.

   Example: *Paramecium*

Order 7 - Thigmotrichida

1. A small group of fresh and marine water ciliates found in association with bivalve molluscs
2. Anterior end of body bears a tuft of thigmotactic cilia.

   Examples: *Boveria, Thigmophrya.*

Subclass (ii) Peritricha

1. Adults without body cilia.
2. The apical end of the body typically bears a conspicuous buccal ciliature.
3. Mostly sessile bearing a stalk.

   It bears a single order-Peritrichida.

   Example: *Vorticella, Carchesium.*

Subclass (iii) Suctoria

1. Sessile and stalked body.
2. Young with cilia. Adult with few to many tentacles.
3. Adult completely devoid of any ciliature.

   This subclass bears only one order-Suctorida.

   Examples: *Ephelota, Podophrya, Acineta.*

Sub-Class (iv) Spirotricha

1. Reduced body cilia.
2. Well developed conspicuous buccal ciliature.

Order. 1-Heterotrichida.

1. With uniform body cilia or body encased in a lorica and body cilia absent.

   Examples: *Stentor, Halteria.*

Order. 2. Oligotrichida

1. Body cilia reduced or absent.
2. Conspicuous buccal membranelles, commonly extending around apical end of body.

   Examples: *Halteria, Strombidium.*

Order 3. Tintinnida

1. Loricete, mostly free swimming ciliates with inconspicuous oral membranelles when extended.
2. Largely marine.

   Examples: *Favella, Codonella.*

Order - 4 - Entodinimorphida

1. Ectocommensel in the digestive tract of herbivorous mammals.
2. Body cilia reduced or absent.
3. Prominent buccal ciliature often in separate anterior clumps.
4. Posterior end may be drawn out into spines.

   Examples: *Entodinium, Cycloposthium.*

Order 5 - Odontostomatida

1. Body laterally compressed and wedge-shaped, with carapace.
2. Reduced body and buccal cilia.

   Example: *Saprodinium.*

Order - 6 - Hypotrichida

1. Body dorso-ventrally flatenned.
2. Body cilia at ventral side, forming cirri.

   Examples: *Euplotes, Urostyla, Oxytricha.*

CHILOMONAS

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Mastigophora
Class	-	Phytomastigophora
Order	-	Cryptomonadida
Genus	-	*Chilomonas*

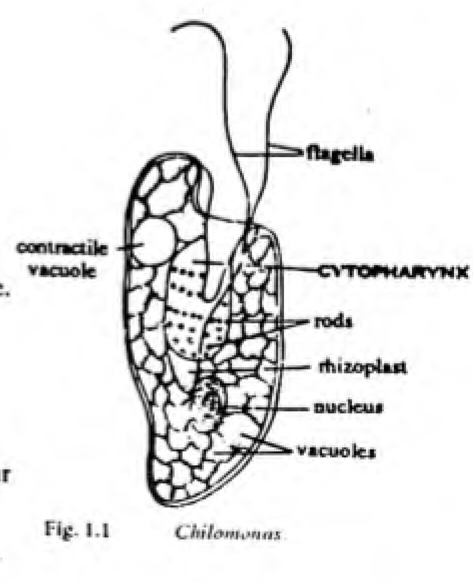

Fig. 1.1 *Chilomonas*

1. It occurs in abundance in stagnant water and is common in laboratry culture.
2. Body is oval, colourless, about 35 μ long.
3. Body with a deep anterior pit, the cytopharynx.
4. Two flagella projecting forwards from the cytopharynx.
5. Endoplasm is distinctly alveolar. Contractile vacuole lies on one side near the anterior end.

6. Nucleus spherical with endosome found at posterior end.
7. Mode of nutrition is saprozoic.

PERANEMA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora.
Super class	-	Mastigophora
Class	-	Phytomastigophora
Order	-	Euglenoidida
Genus		*Peranema*

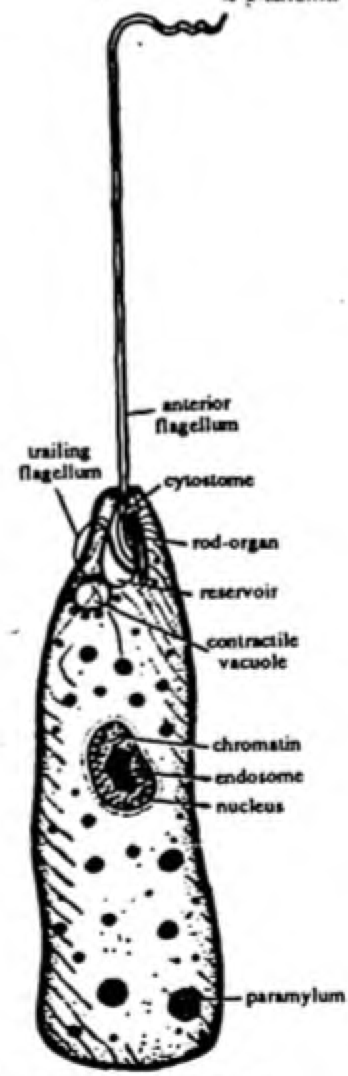

Fig. 1.2 *Peranema* trichophorum.

1. It is widely distributed in stagnant fresh water.
2. Body is covered over by an elastic and spirally striated pellicle.

3. Body is broad and truncated posteriorly and gradually tapers anteriorly.
4. Stigma, para flagellar body and chromatophores are absent.
5. Paired, unequal flagella are present, each arising from its own blepharoplast in the wall of reservoir at anterior end.
6. A pair of hyaline rod-like structures forming the rod organ, running alongside the reservoir and supports the gullet which can be opened or closed.
7. Nucleus is centrally placed with a large; sometimes irregular endosome.
8. It feeds phagotrophically. The prey is siezed by the rod organ and pushed into the cytostome.

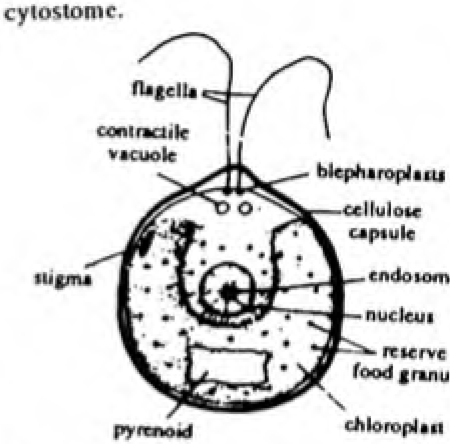

Fig. 1.3 *Chlamydomonas.*

CHLAMYDOMONAS

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Mastigophora
Class	-	Phytomastigophora
Order	-	Volvocida
Genus	-	*Chlamydomonas*

1. It is a solitary animal commonly found in stagnant freshwater. Cosmopolitan.
2. Body is ovoid or flatenned surrounded by a thick cell-wall made of cellulose.
3. It has two flagella, originating from the blepharoplasts situated in endoplasm.
4. Body is green due to presence of a cup-shaped chloroplast. A pyrenoid is embedded in the basal part of chloroplast.
5. Nucleus is vesicular.
6. Red stigma and a pair of contractile vacuoles are found near the base of flagella.
7. Nutrition holophytic i.e. plant-like.
8. Reserve food as starch grain.
9. Asexual reproduction by binary fission, often in the palmella stage.
10. The sexual reproduction by the fusion of flagellate isogamy.

VOLVOX

The systematic position is same as that of *Chlamydomonas.*

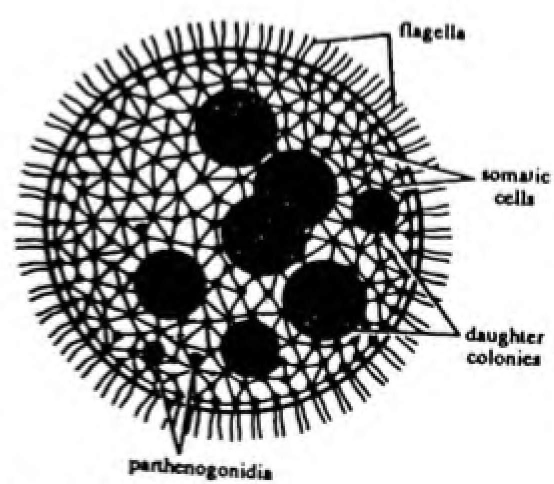

Fig. 1.4 *Volvox* globator.

1. It is a pelagic freshwater, colonial organism found in ponds and lake along with plankton.
2. It has cosmopolitan distribution.
3. The coloney looks like a small green, hollow sphere filled with a watery jelly.
4. Coloney contains thousands of zooids (somatic cells) arranged in a single peripheral layer. The cells are connected by protoplasmic threads and not differing in size.
5. Each zooid has two flagella, two or more contractile vacuoles, cup-like

chloroplast, a single nucleus, a red stigma but no gullet.

6. Nutrition is holophytic.
7. The colonees are polarised since they swim always in one region hence called anterior pole. Locomotion by combined action of flagella.
8. The coloney increases in size by binary fission. The zooids may be sometic and reproductive. The reproductive zooids found posteriorly take part in reproduction.
9. Some of these zooids are called *parthenogonidia* repeatedly divide to form daughter colonies which are liberated by the disintegration of parent coloney.
10. During sexual reproduction some specialized cells, called as *antheridia* give rise to several biflagellate microgametes. Other cells, called *archegonia*, give-rise to non-flagellate macrogametes. Both fuse in water to form zygote that forms new coloney after dormancy.

NOCTILUCA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Mastigophora
Class	-	Phytomastigophora
Order	-	Dinoflagellata
Genus	-	*Noctiluca*

1. *Noctiluca* is a marine and pelagic organism, occurring near the shores often in large number.
2. It is abundantly found in Atlantic and Pacific seas.
3. It has a large, melon-like, bilaterally symmetrical body measuring 1-15. mm. in diameter and enclosed in a firm cuticular pellicle.
4. The cytoplasm is highly vacuolated and differentiated into ectoplasm and endoplasm.
5. In a depression at the ventral pole is a longitudinal oral groove representing the sulcus. This groove has an oval mouth leading into the gullet and two flagella; a long, coarse transversely striated flagellum called tentacle, other in delicate flagellum.
6. From the central sulcus and clump of protoplasm containing the nucleus, various delicate strands run through the watery interior to the periphery.

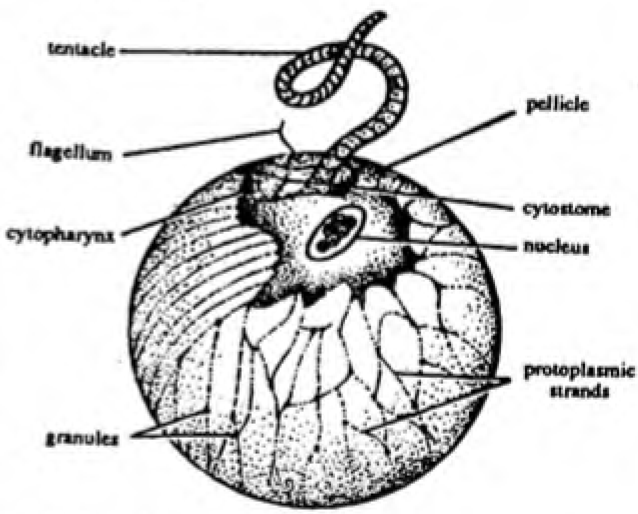

Fig. 1.5 *Noctiluca.*

7. Nutrition is holozoic i.e. animal like.
8. Reproduction takes place asexually by binary fission, as well as by syngamy. The syngamy involves fusion of two organisms and is followed by formation of zoospores.
9. When agitated, it glows with bluish or greenish light. The *luminescence* is caused by photogenic granules *luciferin,* which under the influence of enzyme, *luciferase*, emits light.

CERATIUM

The systematic position is same as in *Noctiluca.*

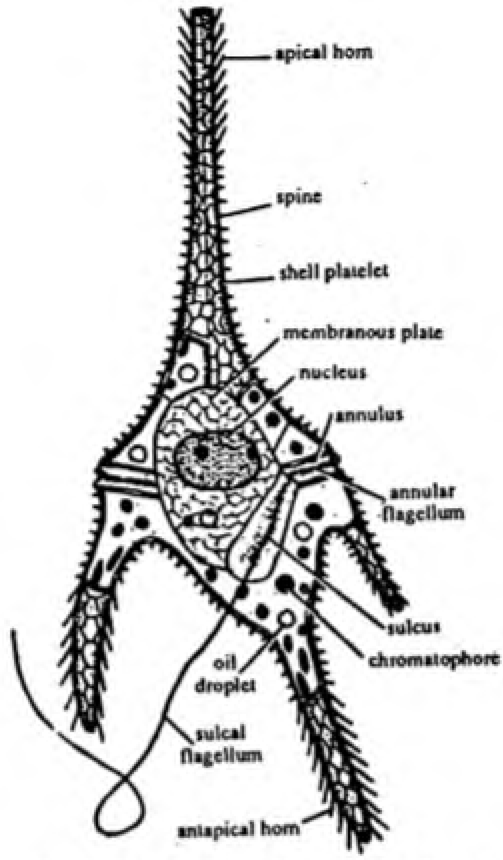

Fig. 1.6 *Ceratium* hirrundinella, semidiagrammatic, with portion of shell removed.

1. *Ceratium* includes marine as well as fresh water species.
2. It is common in U.S.A.
3. The body is usually covered with a cellulose plate grooved by a transverse and a longitudinal furrow each containing a flagellum, which projects out through a pore in theca.
4. The cellulose plates, which are produced into an anterior or apical and two posterio-lateral processes giving it a triangular shape.
5. The transverse groove is called as annulus running, around spiral girdle. Longitudinal groove is called as sulcus.
6. Cytoplasm is differentiated into ectoplasm and endoplasm.
7. Cytoplasm contains starch granules, chromoplast, nucleus and a complex system of contractile vacuoles.
8. It is mainly holophytic but some species are holozoic.
9. Reproduction is by oblique binary fission.
10. Cyst formation sometimes occurs.
11. Several species are known to be luminescent.

PROTEROSPONGIA

Phylum **Protozoa**

Subphylum	-	Sarcomastigophora
Super class	-	Mastigophora
Class	-	Zoomastigophora
Order	-	Choanoflagellata
Genus	-	*Proterospongia*

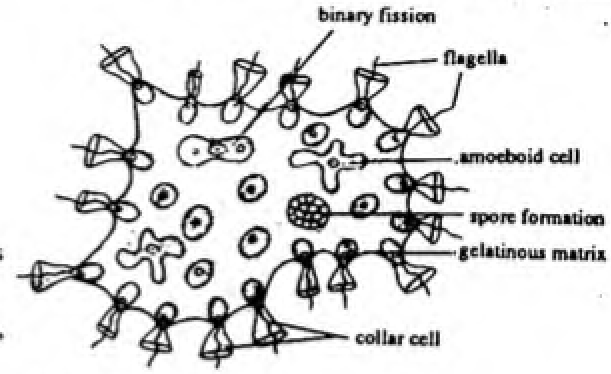

Fig. 1.7 *Proterospongia.*

1. It is a free-living, colonial form.
2. It consists of a gelatinous mass in which upto 60 collared cells lying at periphery.
3. Each bearing a single flagellum surrounded basically by a thin, transparent and funnel-like protoplasmic collar.
4. Collar helps in food capturing or ingestion.
5. Inside the matrix are also some amoeboid zooids.
6. Any collared individuals can migrate inward and change into an amoeboid individual or vice-versa.
7. *Proterospongia* is often regarded as a link between protozoan and sponges.

MASTIGAMOEBA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora.
Superclass	-	Mastigophora.
Class	-	Zoomastigophora
Order	-	Rhizomastigida.
Genus	-	*Mastigamoeba*

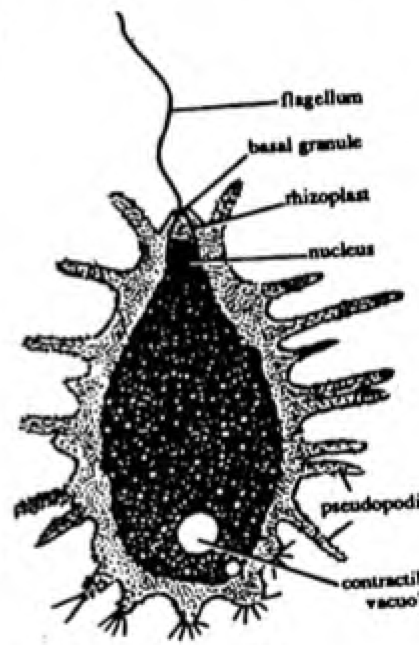

Fig. 1.8 *Mastigamoeba.*

1. It is a free-living flagellate found in fresh water ponds and lakes.
2. Body is irregular or amoeboid in form pushing out several finger like pseudopodia, which usually disappear when the organism swims. One flagellum is present.
3. Protoplasm contains single nucleus and contractile vacuole.
4. Nutrition is holozoic. Pseudopodia help in ingestion of food.
5. It reproduces by a longitudinal binary fission.
6. It is considered to be a connecting link between Mastigophora and Rhizopoda.

BODO

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Mastigophora
Class	-	Zoomastigophora
Order	-	Kinetoplastida
Genus	-	*Bodo*

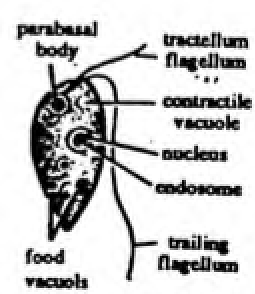

Fig. 1.9 *Bodo* saltans.

1. It is a free-living animal found in the faecal matter.

2. Body is small, naked, more or less elongated, and with one surface more convex than the other.
3. A pair of unequal flagella arise from a depression at the anterior end, one flagellum trailing behind and used for anchoring.
4. Ingestion takes place at a spot near the base of flagella. A permanent cytopyge in not known.
5. Small rostral vacuole and near it is a conspicuous contractile vacuole.
6. Single rounded nucleus with centrally placed endosome lies near anterior end of the body.

TRICHOMONAS

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super Class	-	Mastigophora
Class	-	Zoomastigohora
Order	-	Trichomonadida
Genus	-	*Trichomonas.*

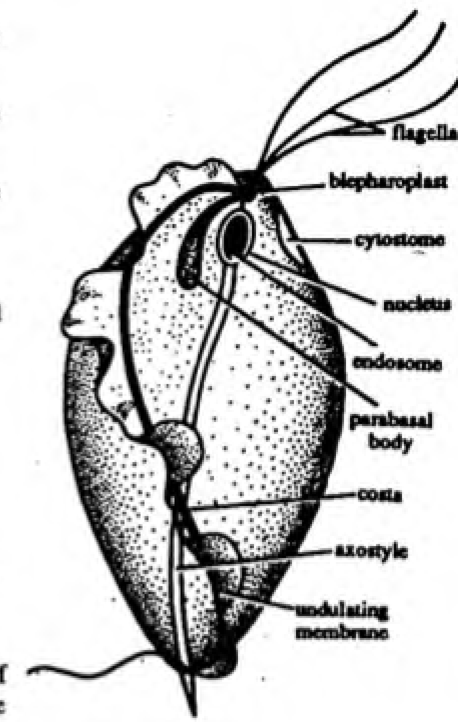

Fig. 1.10 *Trichomonas.*

1. It is one of the most common intestinal multiflagellats, living in the intestine of all the vertebrates and also in leeches and termites. They exist only in the trophozoite phase and have no cystic phase.
2. It has cosmopolitan distribution.
3. The body is bear shaped tapering posteriorly, provided with four flagella of which one is directed backwards united to the body by an undulating membrane. Body measures 5-20 μ in length.
4. Cytostome is present anteriorly, used for ingestion of food.
5. Blepharoplast is minute situated at the anterior end. Extending posteriorly from the blepharoplast is club-shaped parabasal body.
6. A contractile fibre, the *costa* runs along the line of attachment of the undulating membrane.
7. The body is supported by a cylinder of microtobules, the *axostyle,* which extend backwards and projects from posterior end as *spike.* The spike helps to anchor the animal while feeding.
8. The endoplasm contains a large nucleus situated anteriorly. The endosome is prominant.
9. Feeding is saprozoic but most species ingest bacteria, yeast and other solid food.
10. Reproduction takes place exclusively by longitudinal binary fission.
11. No cyst formation as transmission occurs directly in the active, free trophozoite stage.

Pathogenecity In man *Trichomonas buccalis* is found in mouth; *T. homonis* in colon and *T. vaginalis* in vagina of female (*T. vaginalis* is found in large number in the leucorrhoeic discharge of females. It causes inflammation of the vaginal mucosa.) Of other animals *T. foetus* of cattles, *T. gallinae* of birds are important. The disease caused by them is called *trichomoniasis.*

GIARDIA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Mastigophora
Class	-	Zoomastigophora
Order	-	Diplomonadida

Genus *Giardia*

1. *Giardia* is a parasite in the small intestine and colon of man, rats, mice, dogs, cats and frogs. *G. lamblia* is found in the small intestine of man, especially children.
2. Cosmopolitan distribution.
3. Body is oval in shape or half bear-shaped with broad forward anterior end and narrow posterior end.
4. The body is bilateral-symmetrical.
5. The dorsal side is convex, but the ventral surface contains a slight concavity, forming a sucking disc to the wall of intestine.
6. There are two vesicular nuclei and four pairs of long flagella. The basal granules of foremost flagella are inter-connected and also connect with a pair of nuclei.
7. Axostyle forms the median longitudinal axis of the body.
8. Just behind the sucking disc is a deep staining parabasal body.

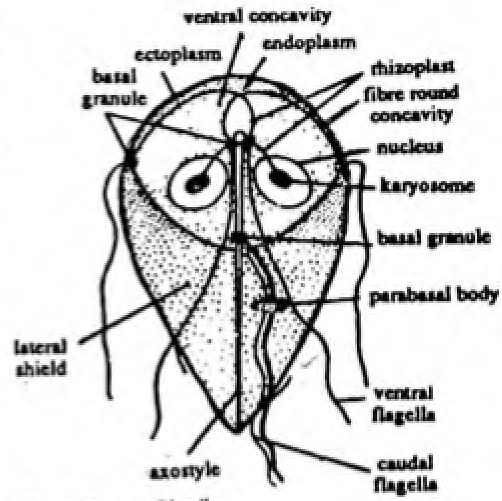

Fig. 1.11 *Giardia*.

9. Cytopharynx is absent and the rhizoplast make complicated loops through the cytostome.
10. Reproduction takes place by longitudinal binary fission.
11. It forms oval thick-walled cysts. Division occurs in the cyst so that the cyst has four nuclei.
12. It prevents absorption of fats by the host, the unabsorbed fat causes diarrhoea.

Pathogenecity: It interferes with the absorption of food and causes chronic enteritis, fever, anaemia, allergy and acute enterocolitis.

TRICHONYMPHA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Mastigophora
Class	-	Zoomastigophora
Order	-	Hypermastigida
Genus	-	*Trichonympha*

1. It is found in the alimentary canal of termites and cockroaches.
2. It is cosmopolitan in distribution.
3. The body is large, more or less oval in shape measures 50-300 μ in length.
4. Body is divisible into three regions: a tapering anterior flagellated rostrum, bearing apical cap; an intermediate bell-like portion, bearing numerous flagella; and a posterior rounded non flagellated region.
5. All the flagella are connected through fibrils with a hemispherical blepharoplast, lying at the base of the cap. Some flagella are arranged in longitudinal rows.
6. Several elongated parabasal bodies and axostylar filament run

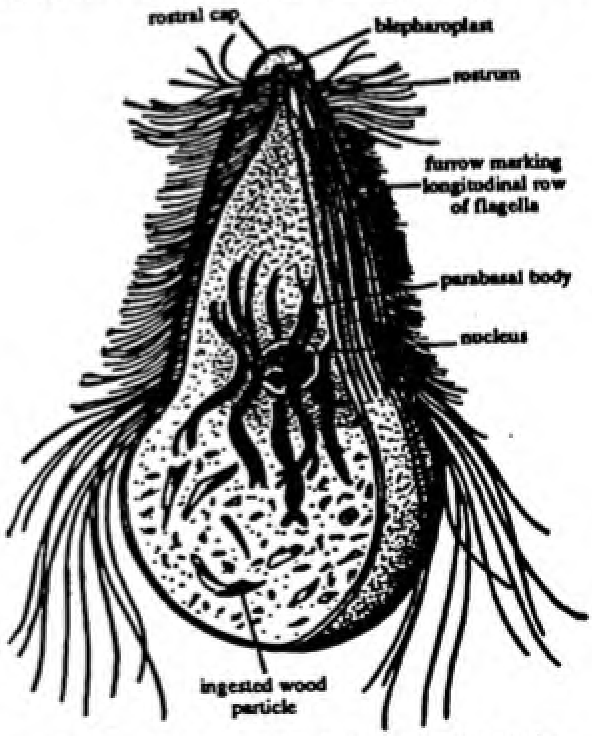

Fig. 1.12 *Trichonympha* collaris, from the western termite.

from rostral to hinder region of body.

7. In the ectoplasm are oblique fibres, an alveolar layer and tranverse myonemes. In the endoplasm are longitudinal myonemes and a nucleus.
8. Reproduction by longitudinal binary fission. Under unfavourable conditions it undergoes encystment.
9. They show symbiosis with the host as they digest cellulose and convert it into soluble carbohydrates for the host.

PELOMYXA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Sarcodina (= Rhizopoda)
Class	-	Rhizopodea
Subclass	-	Lobosia
Order	-	Amoebida
Genus	-	*Pelomyxa*

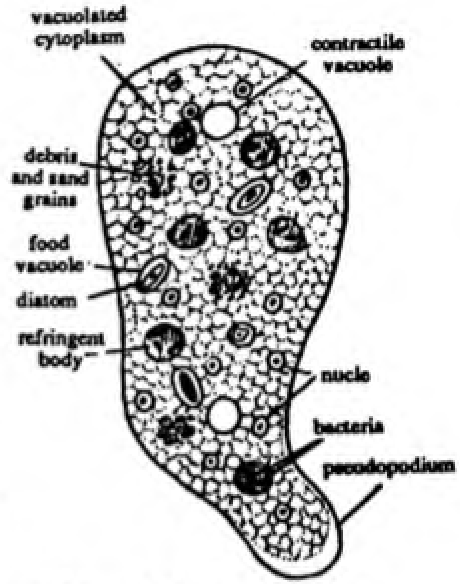

Fig. 1.13 *Pelomyxa.*

1. It is often known as giant-amoeba being about 2.5 mm in length. It is a fresh water form living in the mud of stagnant water.
2. The body is asymmetrical and the body shape changes constantly.
3. It has a single large, hyaline and blunt pseudopodium.
4. The cytoplasm is highly vacuolated and contains 100-1000 nuclei, all of which are alike.
5. It contains a number of peculiar, some-what rounded refringent bodies, which are of albuminous nature and which constantly harbour bacteria of *Cladothrix* sp. (symbiotic).
6. Nutrition is holozoic. Diatoms form the chief food. Numerous food vacuoles, and many fluid filled vacuoles but not contractile vacuoles. Reserve food material in the form of glycogen granules.
7. Asexual reproduction by plasmotomy, in which the cytoplasm divides 2-6 times and each containing few nuclei.
8. Sexual reproduction by the formation of gametes which conjugate in pair. Encystment in some species.

ARCELLA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Sarcodina
Class	-	Rhizopodea
Sub class	-	Lobosia
Order	-	Arcellinida
Genus	-	*Arcella*

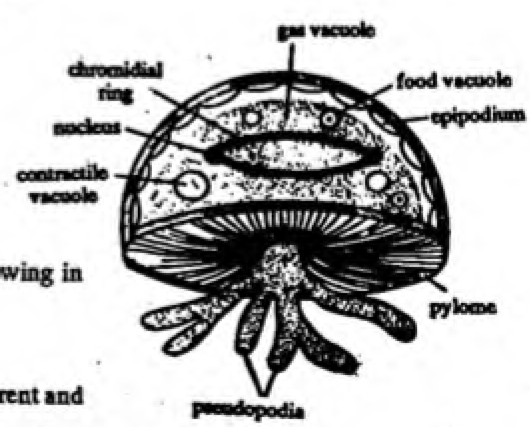

Fig. 1.14 *Arcella.*

1. It is commonly found in stagnant water attached to weeds growing in fresh water. It also occurs in moist forest soil, moss etc.
2. It has cosmopolitan distribution.
3. The body is covered by a yellow to brown, thick, hard, transparent and disc-shaped shall or test secreted by animal itself.
4. The shall is made of pseudochitin containing silica and iron.

5. The ventral surface has an inverted funnel-like depression, leading to central mouth or *pylome*.
6. 1-6 small, hyaline, finger-like, simple or branched lobopodia are extended through the pylome, which function as locomotory organelles and also help in feeding.
7. The cytoplasm is differentiated into nonvacuolated ectoplasm and endoplasm. The body is attached to the inner test by filamentous ectoplasmic strands known as epipodia.
8. Endoplasm contains food vacuoles, contractile vacuoles, reserve food material and two prominant nuclei in *A. vulgaris* and upto 15 in *A. podophrya*.
9. Nutrition is hologoic. Food includes mainly green and colourless flagellates.
10. A characteristic feature is the presence of a ring of granules called *chromidia*.
11. Asexual reproduction by binary fission. Two nuclei divide forming four nuclei, two of which extruded from pylome. This mass secretes a new shall. Multiple fission also occurs.

DIFFLUGIA

Systematic position is same as in *Arcella*.

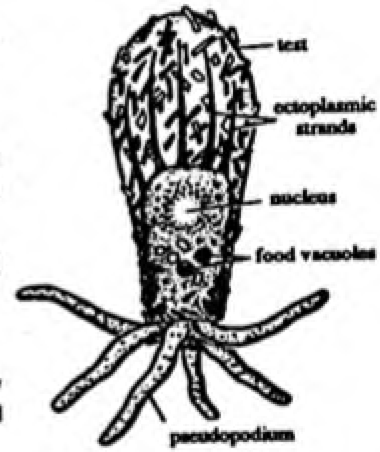

Fig. 1.15 *Difflugia* oblonga.

1. It is a common, free-living animal found on muddy floor of small leaf chacked fresh water puddies, ponds, ditches or even moist soil.
2. It has world wide distribution.
3. It possesses a beautifully symmetrical test usually made up of intricately placed sand grains of a definits size range. In certain localities, diatom shells or spicules of fresh water sponges may be used to supplement the sand grains.
4. The shape of the test (varies with species) may be vase-shaped, or flask-shaped and always has a distinct neck with a terminal mouth or *pylome*.
5. About six slender, hyaline lobose pseudopodia may protrude out from pylome.
6. Cytoplasm is differentiated into ectoplasm and endoplasm. A nucleus surrounded by chromidia; numerous contractile vacuoles and food vacuoles are scattered around the periphery of the endoplasm.
7. Often the animals are a vivid green because of zoochlorellae in their cytoplasm as symbionts.
8. Mode of nutrition holozoic, it feeds upon micro-organisms and filamentous algae such as *Spirogyra*.
9. It reproduces by binary fission, but multiple fission has also been reproted.
10. *Difflugia oblonga* is very active in the spring and most of the summer, but becomes encysted within its test in the late fall.

EUGLYPHA

Systematic position is same as in *Arcella*.

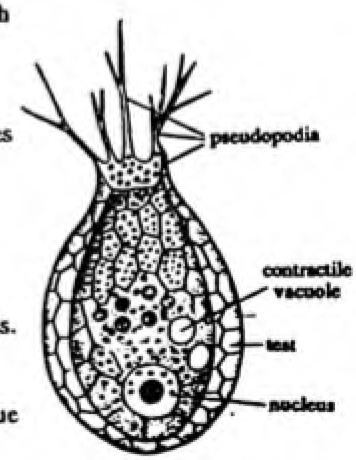

Fig. 1.16 *Euglypia.*

1. It is a freshwater animal found in freshwater, especially common in the sphagnum moss.
2. It has word wide distribution.
3. It has membraneous hyaline, oval, flask-shaped or elongated test composed of oblique rows of close-fitting, overlapping, rounded siliceous scales or plates.
4. The shall opens by denticulate mouth or pylome.

5. The pseudopodia are very fine, filiform, filopodia, which are often branched.
6. Ectoplasm is indistinct. Endoplasm contains shall-plates, vacuoles, one or two large centrally placed nucleus surrounded by perinuclear chromidia.
7. It reproduces by encystment. Multiple fission is not evident.

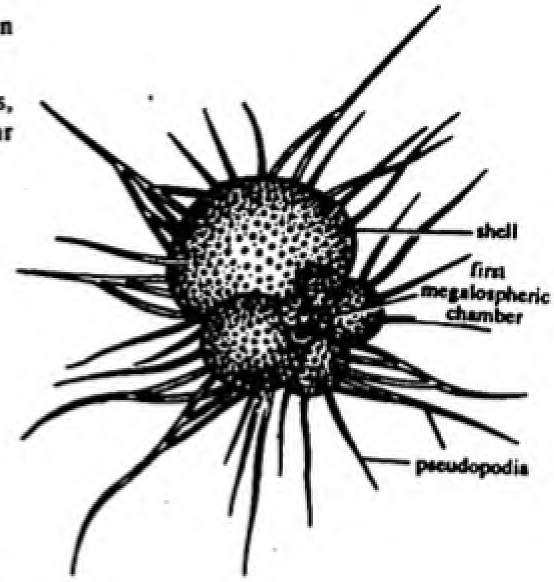

Fig. 1.17 *Globigerina.*

GLOBIGERINA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Sarcodina
Class	-	Rhizopodea
Subclass	-	Granuloreticulosia
Order	-	Foraminiferida
Genus	-	*Globigerina*

1. It is one of the most common and abundant pelagic foraminiferan.
2. It has cosmopolitan distribution.
3. It has a polythalamus perforated and calcareous shall.
4. The chambers are globular, and are arranged in a helicoid spiral.
5. The cytostome occupies all the chambers passing through the opening in the septa.
6. From the shall, long, filamentous, viscous and contractile pseudopodia extend all around. They form pseudopodial network. The pseudopodia are very important. They exhibit streaming movement.
7. Shells of dead individuals sink to the bottom of the sea like rain, forming there a grey mud called the *Globigerina ooze.*

ALLOGROMIA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Sarcodina
Class	-	Rhizopoda
Subclass	-	Filosa
Genus	-	*Allogromia*

1. It is found in both fresh water and marine water.
2. Body of animal is covered by a shall which is one chambered.
3. The cytoplasm flows out from the terminal opening of shall and flows around the shall, in this way shall becomes internal.
4. Cytoplasm contains a single nucleus, a contractile vacuole and a food vacuole.
5. The pseudopodia are very long and delicate, and join to form a network, hence called *reticulopodia.* They help in capturing prey.
6. Reproduction by multiple fission.

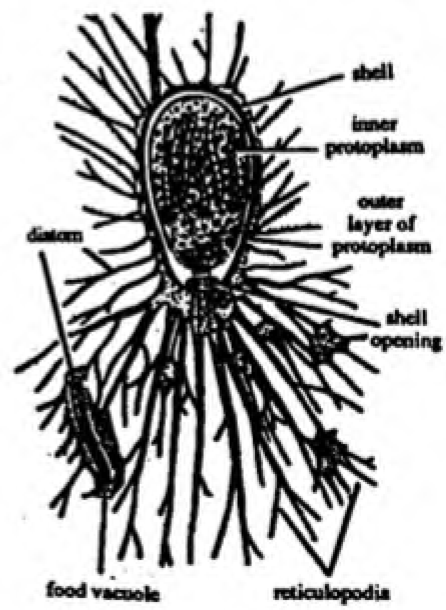

Fig. 1.18 *Allogromia* oviformis.

THALASSICOLA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Sarcordina
Class	-	Actinopodea
Subclass	-	Radiolaria
Genus	-	*Thalassicola*

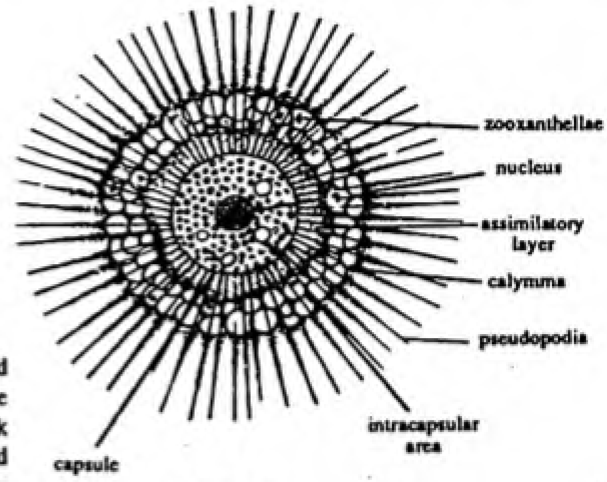

Fig. 1.19 *Thalasicola.*

1. It is a marine, solitary and pelagic.
2. It has a perforated and membraneous central capsule.
3. The intercapsular cytoplasm contains a single large nucleus and a number of small vacuoles. The extracapsular cytoplasm has the usual three regions: inner thin assimatory zone; middle thick vacuolar zone or calymma with large closely-packed, fluid-filled vacuoles lying in gelatinous material and often having yellow symbiotic dinoflagellates; and outer thin pseudopodial region.
4. Contractile vacuole is absent.
5. Nutrition is holozoic.
6. Reproduction by binary fission and swarm-spore formation.

COLLOZOUM

The systematic position is the same as that of *Thalassicola.*

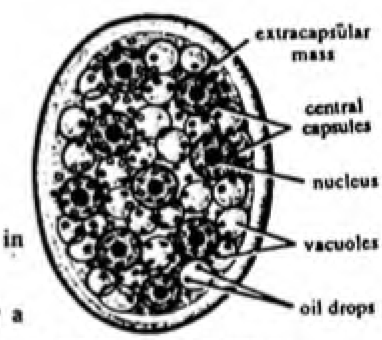

Fig. 1.20 *Collozoum.*

1. It is a large, colonial form having a sub-spherical body measuring about 3-4 cm. in length. They are present in deep sea.
2. Protoplasm is divided into an intracapsular and an extracapsular protoplasm by a perforated membrane, Skeleton is absent.
3. The vacuolated extracapsular protoplasm is common to the entire colony having numerous central capsules embedded in it. Each central capsule indicates a zooid of the colony, which has a single nucleus.
4. The central capsule undergoes repeated divisions, while the extra-capsular protoplasm does not divide.
5. Contractile vacuole is absent.
6. Reproduction by merogony.

LITHOCIRCUS

The systematic position is the same as that of Thalassicola.

1. It is a deep sea, solitary animal with a skeleton.
2. Body is covered by a shall of silicious skeleton.
3. The animal is provided with a central capsule embedded in the protoplasm.
4. The capsule divides the protoplasm into extracapsular and intracapsular protoplasm.
5. Extracapsular protoplasm gives rise to the radiating thread-like pseudopodia. It has symbiotic yellow dinoflagellates.

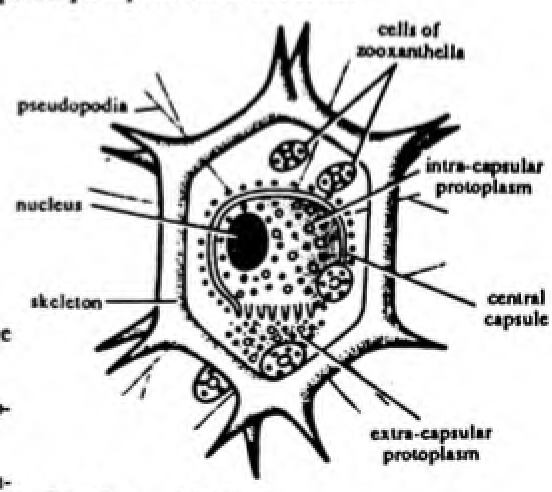

Fig. 1.21 *Lithocircus.*

6. Intracapsular protoplasm contains a large nucleus. Contractile vacuoles is absent.
7. Asexual reproduction by binary fission.

ACTINOSPHAERIUM

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Sarcodina
Class	-	Actinopodea
Subclass	-	Heliozoida
Genus	-	*Actinosphaerium*

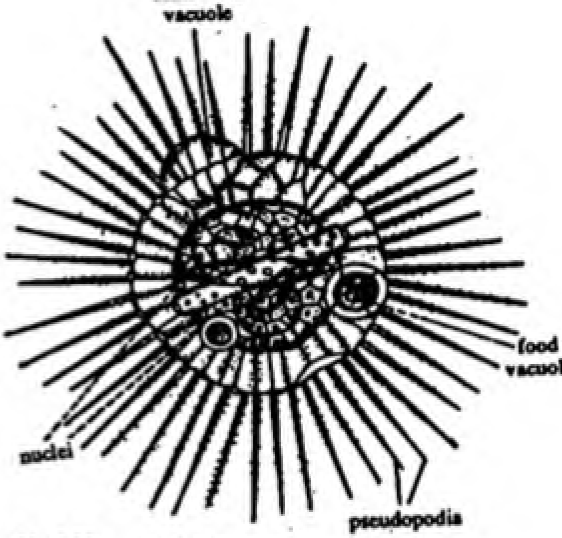

Fig. 1.22 *Actinosphaerium*.

1. It is a fresh water form, abundantly found among floating vegetation. It is commonly called *Sun animalcule*.
2. Cosmopolitan distribution.
3. Several stiff needle-like axopodia radiate from the central spherical body of frothy protoplasm.
4. Protoplasm is divided into a highly vacuolated or frothy ectoplasm and a denser granular endoplasm.
5. Several contractile vacuoles in the ectoplasm.
6. Several nuclei are present in endoplasm.
7. The axial filament of pseudopodia do not reach up to nuclei, but terminate freely in the deeper granular layer of ectoplasm.
8. Nutrition is holozoic, voracious in feeding. Axopodia help in feeding rather locomotion.
9. The animal reproduce asexually by plasmotomy. The whole organism divides into two daughter spheres, each contains several nuclei.
10. Autogamy and encystment also observed.

ACTINOPHRYS

The systematic position is same as that of *Actinosphaerium*.

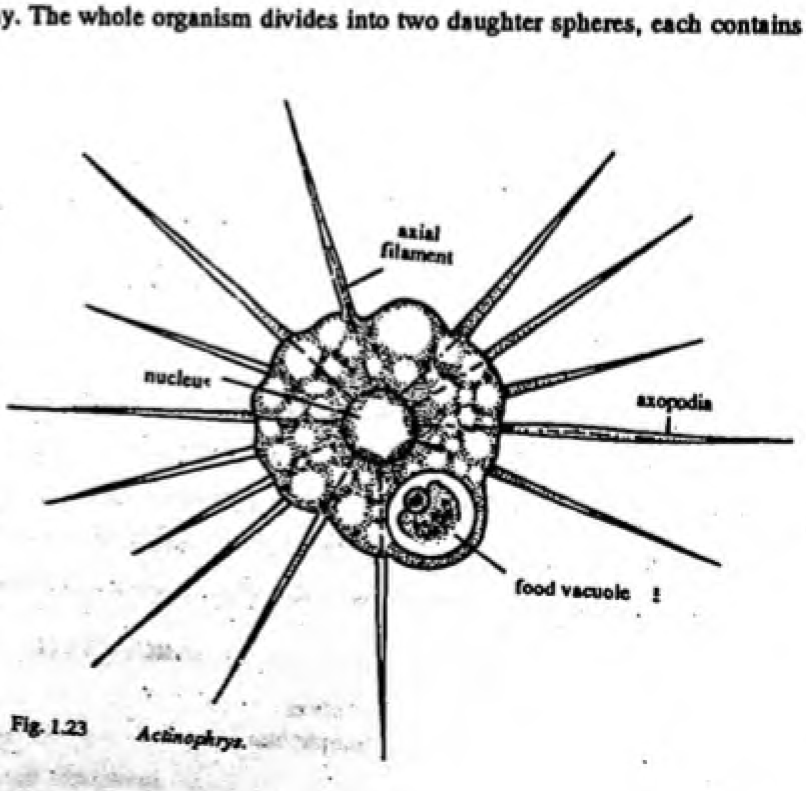

Fig. 1.23 *Actinophrys*.

1. It is found in fresh and marine waters.
2. It has cosmopolitan distribution.
3. The body is round from which radiate thin, long pseudopodia, each with a central axial filament covered with an adhesive granular ectoplasm. They are called axopodia.
4. The axial filaments of axopodia are attached to the nuclear membrane.
5. The cytoplasm is not distinctly divided into ectoplasm and endoplasm.
6. The ectoplasm have many vacuoles.
7. Endoplasm is gelatinous and contains various vacuoles and food particles besides a single

nucleus.

8. Nutrition is holozoic, whenever food or prey touches the axopodia, they attach to it. The axopodia paralyze the prey and at times shorten to convey the prey to central mass of cell.
9. Reproduction occurs by binary fission and also by *paedogamy*. During paedogamy the animal withdraws its pseudopodia gorges itself on flagellates and encysts. The cyst is bilayered outer gelatinous and membranous inside. It divides into many uninucleate cysts. Each secondary cyst divides into two cells enclosed in the cyst. The nucleus of each cell than divide twice to form four haploid nuclei. Two of the nuclei degenerate. The remaining two nuclei of cyst cells then fuse to form zygote. The zygote reproduces by binary fission and the daughter cells escape from the cyst, they grow into adults.

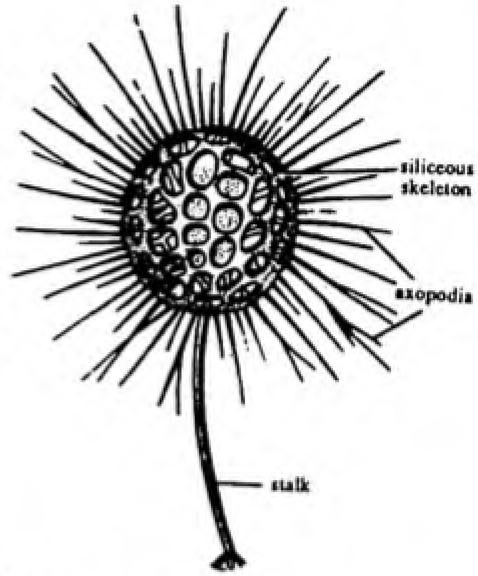

Fig. 1.24 *Clathrulina.*

CLATHRULINA

The systematic position is same as that of *Actinosphaerium.*

1. It is a fresh water protozoan.
2. The body is enclosed in a perforated skeletal sphere of silica, and is attached by a long, slender stalk.
3. The axopodia project through the skeletal investment.
4. Cytoplasm contains single nucleus.
5. It undergoes multiple fission in the active condition and produce biflagellate merozoites, called *flagellule*. The flagellule latter grow into adults.

BABESIA

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Super class	-	Sarcodina
Class	-	Piroplasmea
Genus	-	*Babesia*

Fig. 1.25 *Babesia.*

1. It is a minute, intracorpuscular blood parasite of cattles, dogs and monkeys
2. The trophozoite lives in the R.B.C. of the host and has a rhizoplast but no flagellum and pigment.
3. Tick is the intermediate host and vector. Upon reaching in its gut, the trophozoites change into gametes and fuse in pairs to form zygote.
4. The zygotes are motile and bore the alimentary canal and reach the ovary and parasitize the ova.
5. In ova they divide and produce amoeboid spores which pass on to the next generation of host (tick).
6. Some of the spores reach the salivary glands cells where the spore becomes multinucleated and produce sporozoites.
7. Tick transfer the sporozoites into the blood of the primary host when it feeds upon its blood.
8. It causes the formidable Texas Fever or Red Water Fever in Cattles in America and Australia.

SARCOCYSTIS

Phylum	-	Protozoa
Subphylum	-	Sporozoa

Class	-	Toxoplasmea
Genus	-	*Sarcocystis*

1. It is a muscle parasite of vertebrates especially sheep, rabbit, pigs, rats, cattles, horses and in reptiles and birds.

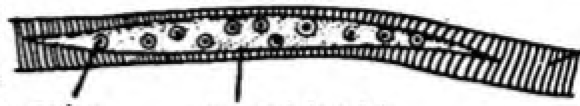

Fig. 1.26 *Sarcocystis.*

2. The parasite usually encysts within a striped muscle fibres of the host, forming a long multinucleate spindle-like cyst which may be several mm. in length. It is known as *Miescher's* or *Rainey's tube.*
3. Within each tube a large number of sickle-shaped spores are formed. The spores are called *Rainey's corpuscles.*
4. Very little is known about the mode of transmission and life cycle. When ingested the spores hatches in the intestine of new host liberating a single sporozoite, which penetrates an epithelial cell to grow into a trophozoite through blood circulation it reaches to the striped muscle fibres, where it grows into plasmodium.
5. They produce a toxic substance *sarcocystin* and cause a disease known as *sarcosporidiosis.*

NOSEMA

Phylum	-	Protozoa
Subphylum	-	Cnidospora
Class	-	Microsporidea
Genus	-	*Nosema*

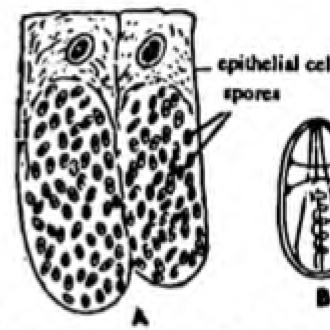

Fig. 1.27 *Nosema.* A—Spores of Nosema apis in stomach cells, B—Spore of N. bombycis.

1. *Nosema bombycis* is a parasite in the gut of silk worm larvae where it causes *Pebrine - a* destructive silkworm disease.
2. Asexual multiplication of the trophozoites and possibility of some spores developing in the same host cause enormous damage to the hosts's tissue, the result is fatal.
3. Its another species is *N. apis.* It is parasite in the epithelial tissue and the Malpighian tubules of honey-bees causing a fatal disease *nosema.*
4. The spores are very small, each containing a coiled thread, the *polar filament,* that represents a polar capsule without a wall.

PRODODON

Phylum	-	Protozoa
Subphylum	-	Ciliophora
Class	-	Ciliata
Subclass	-	Holoricha
Order	-	Gymnostomatida
Genus	-	*Prorodon*

1. It is a fresh water and marine ciliate.
2. The body is ovoid but sometimes variable in shape, but, when fully extended, it measures 165-200 µ in length and 40-60 µ in width.
3. Body is ellipsoidal, with the anterior end slightly wider then the posterior.
4. Body is covered over by cilia. The cilia of anterior and posterior ends are somewhat, longer than elsewhere.
5. The terminal cytosome leads into a short oval cytopharynx.
6. The cytoplasm is differentiated into ectoplasm and endoplasm.

Fig. 1.28 *Prorodon griseus.*

7. Ectoplasm of *P. griseus* contains no trichocysts or other inclusions except 20 - 30 deeply, embedded, large, parallel, rod - like trichite. These form a highly distensible oral basket around the subterminal cytostome.
8. Endoplasm is grayish and occasionally may become green because of presence of numerous symbiotic zoochlorellae.
9. Numerous food vacuoles are present. Cytopyge at the posterior end.
10. A large contractile vacuole is present at extreme posterior end.
11. Two *nuclei* ; the massive macronucleus located centrally, may be spherical or oval containing a prominent nucleolus. A small pear-shaped micronucleus is found attached externally to the macronucleus.
12. When the pond water dry up, it develops a thick-walled protective cyst around itself. Almost immediately after excysting, the small animals conjugate followed by binary fission. Macronucleus also divides.
13. Macronuclear reorganization takes place only in the permanent protective cyst and requires at least four days.

COLEPS HIRTUS

The systematic position is same as that of *Prorodon*.

1. It is a widely distributed fresh water ciliate with an ability to tolerate wide range of temperature, oxygen, salinity and acidity.
2. The body is barrel shaped, brown in colour and is slightly more convex dorsally. It measures about 40-65 μ in length and 20-30 μ in width.
3. In the alveolar layer of ectoplasm beneath the pellicle, the body is covered with armor plates which are modified into oral teeth at the anterior end, and caudal spines at posterior end.
4. The plates are organic in composition and are arranged in four anterioposterior girdles of 20 plates each which encircle the animal, like the staves of a barrel.
5. Each plate bears elevated rectangular areas that give the surface of the ciliate the appearance of being divided into more or less symmetrical squares.
6. Shorter cilia located between the longitudinal plates and longercilia occur around the anterior cytostome. Longer cilia help in locomotion.

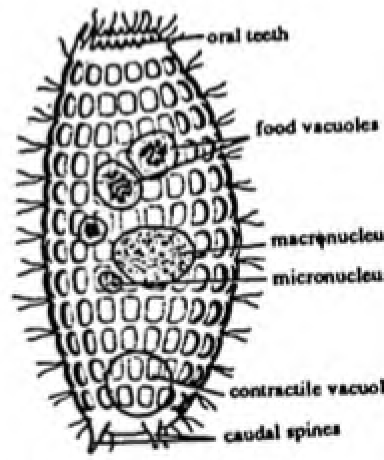

Fig. 1.29 *Coleps hirtus.*

7. The animal is scavanger. It ingests large protozoans and green flagellates.
8. Endoplasm contains many food vacuoles, a posterior contractile vacuole and two nuclei. The macronucleus is centrally placed and is spherical, the micronucleus is small.
9. A subterminal pygostyle is present.
10. Asexual reproduction by binary fission. Conjugation is not reported in this animal.

DIDINIUM NASUTUM

The systematic position is same as that of *Prorodon*.

1. It is fresh water protozoan found in ponds and ditches where large protozoan like *Paramecium, Colpoda, Frontonia* etc. are in abundance.
2. It is commonly known as 'water bear'.
3. Body is barrel - shaped, measuring 80 - 200 μ in length, and produced at the anterior end into a conical proboscis that bears cytostome at the tip.
4. The cilia occur in two rings only, one ring of cilia is close to the base of proboscis and the other ring on the posterior end.

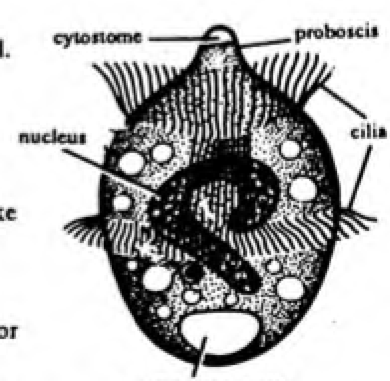

Fig. 1.30 *Didinium.*

5. The trichocyst - like bodies are present only in proboscis region.
6. Within the endoplasm, a horse - shoe shaped macronucleus may be seen; a contractile vacuole and cytopyge are both in the extreme posterior end of the animal.
7. The animal is voracious. Its enormous appetite is satisfied by a diet of large ciliate like *Paramecium* etc.
8. Asexual reproduction by binary fission at a rate of 3-4 divisions per day.
9. Sexual reproduction by conjugation. It encysts under unfavourable conditions.

COLPODA CUCULLUS

Phylum	-	Protozoa
Subphylum	-	Ciliphora
Class	-	Ciliata
Subclass	-	Holotricha
Order	-	Trichostomatida
Genus	-	*Colpoda*
Species	-	*cucullus*

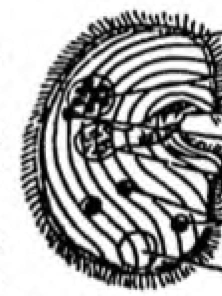

Fig. 1.31 *Colpoda cucullus*, oral view.

1. It is free - living, freshwater ciliata.
2. The shape of animal superficially resembles a flatenned kidney. It measures 80-120 μ in length.
3. A clear defined, diagonal groove is located on the aboral surface extending from the right side of the posterior third of body to the middle where it forms a prominant notch. The groove continues for a short distance on the cytostome lying near the left side.
4. Cilia are present on the right side of cytopharynx and rows of cilia on the left side of same organelle give that area a cross - hatched appearance. Delicate cilia throughout the body.
5. Ectoplasm possesses small clear trichocysts which have a doubtful function in this species.
6. In the endoplasm a spherical macronucleus, a small micronucleus are present in the middle region. A contractile vacuole present at the posterior end. Many food vacuoles are present.
7. Binary fission takes place in thin walled cyst.
8. Under unfavourable conditions thick walled cysts are formed. The encysted *Colpoda* remains in a dormant state for long periods of time and may become active again even after 38 years.

BALANTDIUM

Phylum	-	Protozoa
Subphylum	-	Ciliophora
Class	-	Ciliata
Subclass	-	Holtricha
Order	-	Trichostomatida
Genus	-	*Balantidium.*

1. It is commonly found in the intestine of man, pigs, sheep, camels, cockroaches etc. It is abundantly found in the rectal contant of the frogs.
2. It has cosmopolitan distribution.

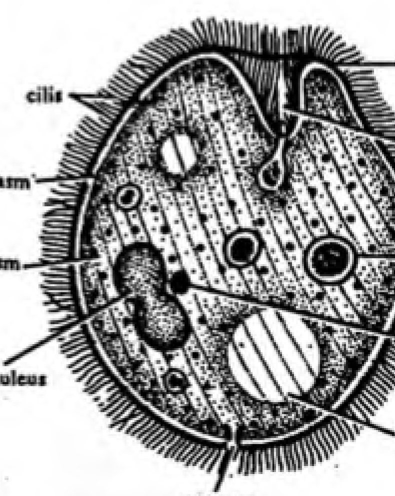

Fig. 1.32 *Balantidium* coli.

3. It is spherical in shape measuring 60-70 μ in length and 40-60 μ in breadth.
4. The entire body is covered by longitudinal slightly spiral rows of cilia.
5. There is a large peristomal depression or vestibule leading to cytostome at the anterior end.
6. Broad posterior end bears a cytopyge.
7. Cytoplasm is differentiated into ectoplasm and endoplasm.
8. The endoplasm contains food-vacuoles, two contractile vacuoles and two nuclei. The macronucleus is large rod-like while micronucleus is small and spherical.
9. Nutrition is holozoic. Food consists of erythrocytes, tissue fragments, bacteria and faecal debris.
10. Reproduction takes place by binary fission and conjugation.
11. Cysts are formed, but no multiplication occurs inside the cysts.

Pathogenicity: It causes ulceration of the colon and invades the mucosa by virtue of *cytolysin*, which it is believed to secrete. It generally cause diarrhoea, but sometimes cause severe or fatal dysentery.

NYCTOTHERUS

The systematic position is same as that of *Balantidium*.

1. It is a parasitic ciliate in the rectum of frogs and intestine of cockroaches.
2. It has worldwide distribution.
3. Body is bean-shaped dorsoventrally flatenned and measures 60-120 μ in length.
4. The peristome starts from the anterior end and extends down to the middle of left side, where it leads by cytostome into a curved cytopharynx.
5. The entire body of animal is covered with short equal-sized cilia arranged in longitudinal rows. Peristome bears an adoral row of specially large cilia, that extended into the cytopharynx.

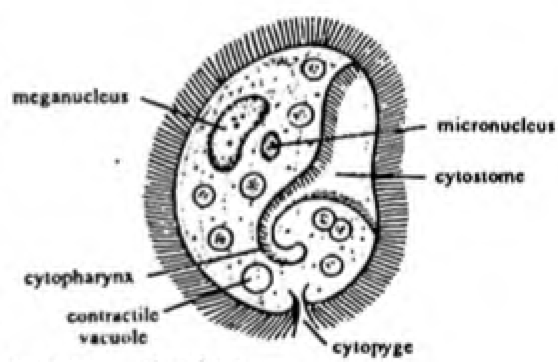

Fig. 1.33 *Nyctotherus*.

6. A permanent cytopyge at the posterior end of the body.
7. Cytoplasm is differentiated into ectoplasm and endoplasm.
8. Endoplasm encloses several food vacuoles, a large contractile vacuole (at the posterior end); a kidney shaped macronucleus and a small micronucleus infront of cytopharynx.
9. Nutrition is holozoic. Food consists of bacteria, undigested food particle etc.
10. Asexual reproduction by binary fission. Sexual by conjugation.
11. Encystment during breeding season of host. The cysts are swallowed by the tadpoles with vegetation.

FRONTONIA

Phylym	-	Protozoa
Subphylum	-	Ciliophora
Class	-	Ciliata
Subclass	-	Holotricha
Order	-	Hymenostomatida

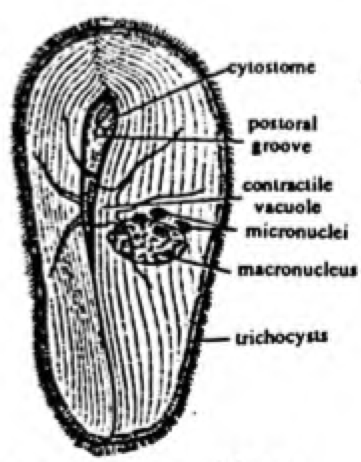

Fig. 1.34 *Frontonia* leucas.

Genus - *Frontonia*

1. It is a large fresh water animal.
2. The anterior end of body is somewhat flattened dorsoventrally, where as the posterior end is more cylindrical. It measures 150-300 μ in length and the width 70-150 μ.
3. The body is uniformly covered with cilia except the oral region.
4. Cytoplasm is differentiated into ectoplasm and endoplasm.
5. Embedded in the ectoplasm are numerous fusiform trichocysts, usually right angles to and in contact with pellicle.
6. Located ventrally in the anterior fourth or third of the body, the cytostome proper in more or less heart shaped with its point toward the anterior end. From this side a very narrow postoral groove extends almost to the posterior end of the body, then swings toward the opposite side at posterior end.
7. Endoplasm contain a very large contractile vacuole surrounded by 8-10 radial canals.
8. At the same level of the contractile vacuole is a large oval macronucleus. Many (3-5) micronuclei are found near macronucleus.
9. It is omnivorous feeds on bacteria, alagae, amoebae, arcellae and even rotifers.
10. Symbiotic zoohlorellae sometimes occur in the cytoplasm.
11. Reproduction by binary fission and conjugation.

CARACHESIUM

Phylum	-	Protozoa
Subphylum	-	Ciliophora
Class	-	Ciliata
Subclass	-	Peritriche
Order	-	Peritrichida
Genus	-	*Carachesium*

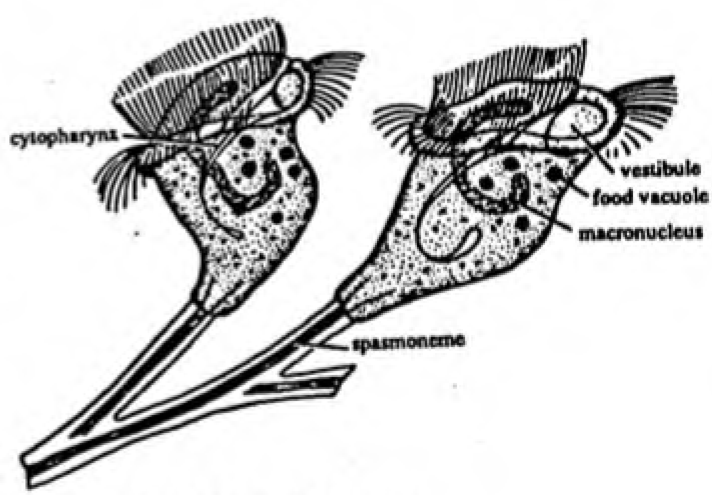

Fig. 1.35 Zooids of *Carchesium polypinum.*

1. It is fresh water as well as marine colonial ciliate with branching stalks.
2. The zooids are bell-shaped and largely resemble *Vorticella* in structure.
3. The stalk of each zooid has a separate spasmoneme so that it contract independently of the stalks of other zooids in the coloney.
4. The arrangement of cilia reaches its greatest complexicity in the adoral or oral ciliature.
5. Endoplasm contains macronucleus and micronucleus, food vacuoles and contractile vacuole.
6. It reproduces by binary fission, conjugation and sometimes encystment occur.

STENTOR

Phylum	-	Protozoa
Subphylum	-	Ciliophora
Class	-	Ciliata
Subclass	-	Spiroptricha
Order	-	Heterotrichida

Genus *Stentor*

1. It is a large, sessile, fresh water ciliate, having a sky-blue pigment called as *stentorin*.
2. It has world-wide distribution.
3. It measures 1-4 mm. in length and is pyriform in shape.
4. The body is covered over by cilia, arranged in longitudinal rows.
5. The animal attaches itself to aquatic plants, animals and other solid objects by its lower narrower end, which gives out pseudopodia to serve as holdfast.
6. In some species the lower end in covered by a loose gelatinous tube.
7. The anterior ends bears a broad peristome encircled by a single row of adoral memberanelles arranged spirally in a clock-wise manner.
8. The peristome spirals down to the cytosome that leads into a short tabular cytopharynx.
9. The nuclear apparatus consists of a long beaded macronucleus with 15-20 beads or lobes and about 80 micronuclei lying close to the macronucleus.
10. Single contractile vacuole with a very long feeding canal.
11. Nutrition is holozoic. Food consists of small flagellates and rotifers.
12. Reproduction by binary fission. Conjugation also occurs in late spring.
13. The largest size of body and nucleus make it an excellent material for the study of behaviour, grafting and regeneration in the laboratory.

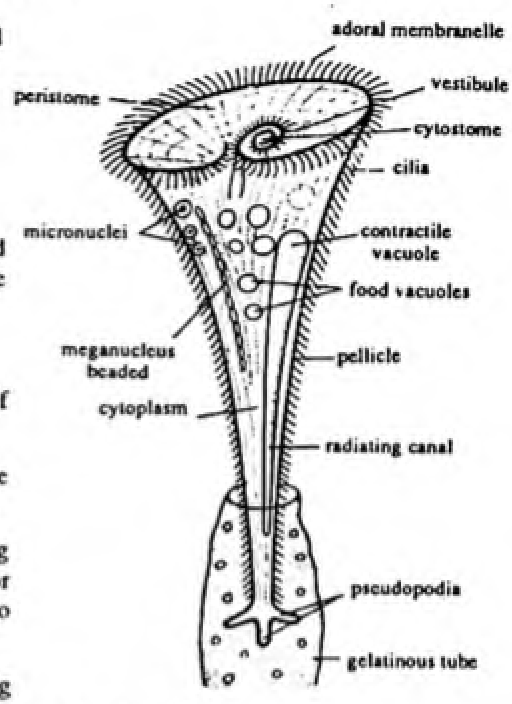

Fig. 1.36 *Stentor*.

SPIROSTOMUM

The systematic position is same as that of *Stentor*.

1. It is a fresh-water, free living animal.
2. It has a slim, long, cylindrical and worm-like body, measuring 3-4 mm in length.
3. Body shows anticlock-wise spiral striations.
4. Highly developed contractile myonemes run longitudinally in the ectoplasm.
5. Peristome, occupying nearly 1/3 anterior ventral surface of the body.
6. The cilia are short, uniform except for some caudal cilia which are slightly larger, secrete mucous.
7. A large contractile vacuole and cytopyge lie at posterior end of the body.
8. Nuclear apparatus consists of a long beaded macronucleus and several micronuclei.
9. They undergo conjugation and a complicated process of binary fission.

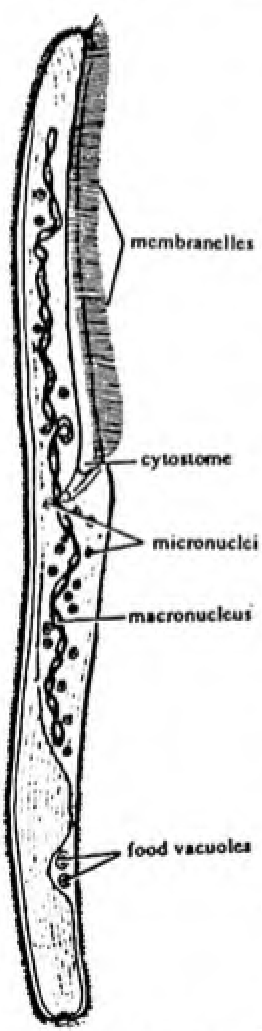

Fig. 1.37 Oral view of *Spirostomum ambigumm*.

STYLONCHIA

Phylum	-	Protozoa
Subphylum	-	Ciliphora
Class	-	Ciliata
Subclass	-	Spiroptricha
Order	-	Hypotrichida
Genus	-	*Stylonchia.*

1. It is one of the most prevalent ciliate found in infusion culture made from natural waters or soils.
2. The body is elongated, oval, rigid and depressed with an arched dorsal surface and flat ventral surface. It measures 150 μ in length.
3. The sides of the body are fringed with marginal cirri which are made up of fused cilia in bundles.
4. The ventral surface bears an elaborate system of cirri, including 8 frontals, 5 ventrals, 5 annals, and 3 caudals.
5. The cilia of dorsal surface are represented by few stiff bristles.
6. Peristome is triangular or semicircular. It begins at the anterior end and reaches upto middle of the body.
7. Cytostome remains permanently open.
8. Mode of nutrition holozoic. It takes bacteria, green flagellates. Cannibalism in the scarcity of foods.
9. Two large, oval macronuclei and two small micronuclei. Contractile vacuole is single.
10. Reproduction mainly by transverse binary fission. Conjugation also takes place.

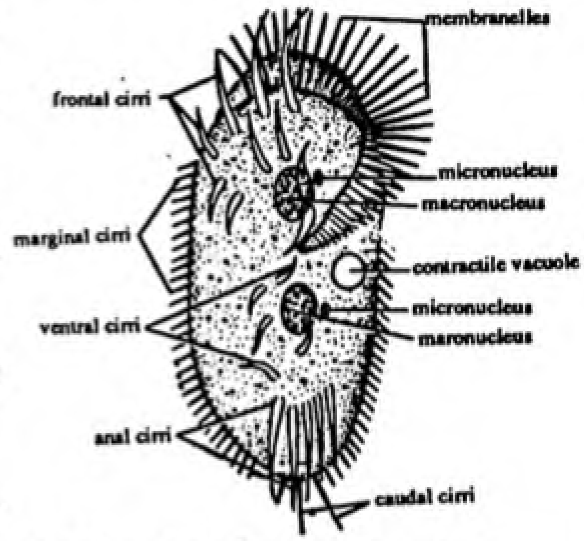

Fig. 1.38 Oral view of *Stylonychia pustulata*

EUPLOTES PATELLA

The systematic position is same as that of *Stylonchia*

1. It is found in fresh water and brackish water.
2. Body is subcircular to elliptical with dorsal side convex and the ventral side concave. It measures 90 μ in length and 50 μ in width.
3. On the dorsal side there are six distinctive ridges with corresponding rows of sensory bristles embedded in rosettes of granules.
4. The ventral surface bears the cirri, of which 6 are frontals, 3 ventral, 4 annals and 4 caudals.
5. A small peristomial field is surrounded by 34-35 memebranelles arranged in a spiral manner. On the right there is somewhat raised peristomial lip.
6. Undulating membrane is absent.
7. Dense endoplasm contain a C-shaped macronucleus. Small micronucleus lies near the macronucleus.
8. A contractile vacuole lies dorsally.

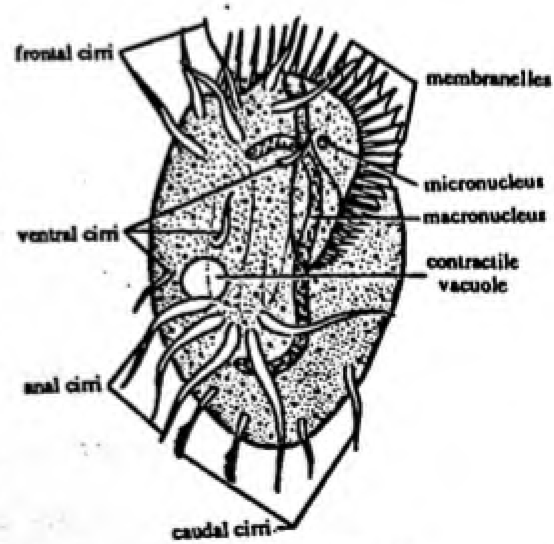

Fig. 1.39 Oral view of *Euplotes patella.*

9. An ill-defined cytopyge is present.
10. Mode of nutrition holozoic. It chiefly feeds upon *Chilomonas.*
11. It multiplies by binary fission.
12. Conjugation also takes place among the different mating types of a syngen.

EPHELOTA

Phylum	-	Protozoa
Subphylum	-	Ciliophora
Class	-	Ciliata
Subclass	-	Suctoria
Genus	-	*Ephelota*

1. It is a large marine form, found in the sea-water. It remains attached various objects like algae etc.
2. The body is spherical and bears a stalk.
3. Two types of tentacles are present on body; long pointed for piercing the prey and short tentacles are cylindrical for sucking.
4. Cytoplasm contains few contractile vacuoles. The macronucleus is highly branched. Micronucleus is small.
5. The distal end bears a number of buds, each receiving a branch of macronucleus. The nuclei behave as in ordinary binary fission. Thus mode of reproduction is by exogeneous buds. The buds detach and acquire cilia on one surface. After a short active free-swimming existence, they lose cilia and grow into tentaculate adults.

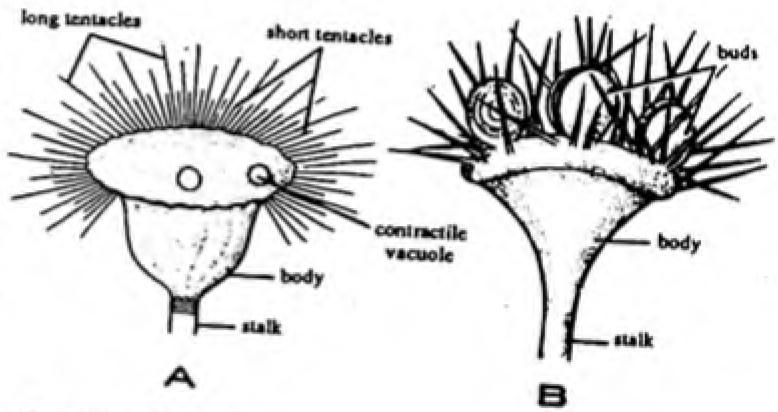

Fig. 1.40 *Ephlota.*

PODOPHRYA

The systematic position in same as that of *Ephelota.*

1. It is a fresh water from remains attached to the subsetratum.
2. Body is divisible into a globular part and a stalk, the globular part measures 40-50 μ in diameter.
3. The body bears a number of tentacles that give a pin-cushion like appearances. They are evenly distributed. They consist of a core of fluid endoderm surrounded by a firm ectoplasm.
4. The cytoplasm contains a large spherical macronucleus in the centre and several micronuclei.
5. A single contractile vacuole near the periphery. The entire body is covered by a gelatinous sheath.
6. Mode of nutrition is holozoic. It feeds other ciliates. The chief food in *Paramecium.* As soon as the tentacles come in contact with the prey, additional tentacles join in holding and eating it.

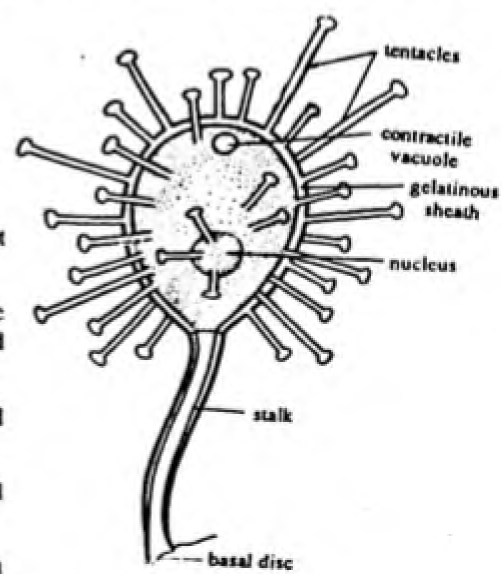

Fig. 1.41 *Podophrya.*

7. Reproduction by external budding. A bud is an out growth of the body. It receives parental cytoplasm, a part of parental macronucleus and micronuclei (derived from the parental micronuclei by regular division). The bud acquiring cilia and finally separates from parent. After free-swimming the bud comes to rest and attach itself by one end. It grows and given rise to an adult.

8. Conjugation takes place by the fusion of two adjacent stalked adults. Encystment during unfavourable conditions.

2

EUGLENA

Euglena belongs to the Order - Euglenoidida (class - Mastigophora), which comprises relatively large forms, usually of a conspicuously green colour. In the members of this order one or two flagella are present, arising from the invaginated anterior end of the body called *reservoir.* All chlorophyll bearing members posses a light-sensitive organelle called *stigma.* Several non-pigmented forms e.g. *Peranema* etc. are also place in this order because of their basic structure.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Subphylum	-	Sacromastigophora
Superclass	-	Mastigophora
Class	-	Phytomastigophora
Order	-	Euglenoidida
Family	-	Euglenoidae
Genus	-	*Euglena*

Habits and Habitat

Euglena is a common, solitary and free-living flagellate found in stagnant water containing nitrogenous organic matter. Such water with high organic contents is called *polysaprobic.* Water with medium organic contents is called *mesosaprobic* and with low organic contents as *oligosaprobic.* The pure water is described as *kathrobic.* There are about 100 species of *Euglena* widely distributed all over world in polysaprobic fresh water. It is known to occur in soil, mud and often has been found on the bark of trees. *Pringsheim* (1953) mentioned that some euglenae are marine and some are parasite *Euglenomorpha* lives in the rectum of tadpoles, where they play an unknown symbiotic role. The most common species of *Euglena* is *E. viridis.* The common Indian species are *E. agilis, E. orientalis* and *E. fusiformis.* The present description is based on the biology of *E. viridis* (*Gr. eu* = true; *glene* = eyeball; and *L., viridis* = green). They are found in such a large number that they produce a green screen on the surface of ponds.

Culture

They can be cultured in laboratory. For preparing culture, some cow or horse dung in boiled in water in a jar and allowed to cool it for two days. Now pour some weeds from the pond containing euglenae into the jar and place the jar near the light source. In a few days euglenae develop in the medium. Another method can be utilized for the preparation of culture. Boil the pond or tap water for some times and allow to cool it. Add 20 boiling wheat grains to this water and inoculated with euglenae. Keep the jar in sunny place. Wheat grains may be added monthly to maintain the culture.

Morphology

Shape and size. Euglena viridis is a minute elongated and spindle-shaped. It is pointed at the posterior end blunt at the anterior end. The posterior blunt end is called *tailpiece.* It measures 60u in length and 15-20u in breadth at the thickest part of the body.

Pellicle. The shape of the animal is maintained by the pellicle which presents parallel or spiral striations. The striations may or may not be present on the tailpiece. According to *Chadfaud* (1937) the pellicle is two layered, having an outer thin *epicuticle*

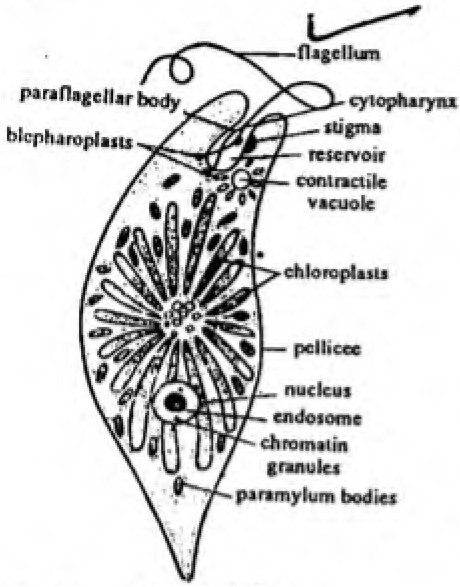

Fig. 2.1 *Euglena* viridis

and deeper and thick inner *endocuticle.* The pellicle in soft and thin and enabling the animal to change its shape considerably. The pellicle is made of proteins but not of cellulose. Under electron - microscope the pellicle consists of interlocking longitudinal strips and usually associated with microtubular fibrils, the *myonemes* (*Leedale, 1964*).

In some species of *Euglena* just below the pellicle very small elongated or spherical bodies are present, these are believed to secrete mucilage and hence are called *mucous bodies* or *muciferous bodies.*

Cytostome and cytopharynx. Shortly to one side of the middle line, at the anterior end, is a small opening called *cytostome* or cell mouth. The cytostome leads into a tube called *gullet* or *cytopharynx* which in turn opens at its other end into a more or less spherical chamber called the *reservoir.* The pellicle invaginates into the gullet through the cytostome and lines the reservoir. The pellicle here contains only the epicuticle layer.

The cytostome and gullet are not used for the ingestion of food but as a canal for the escape of fluid from the reservoir.

Contractile vacuole. A large contractile vacuole lies towards one side of the reservoir. It is surrounded by several small accessory vacuoles. The contractile vacuole receives water from the accessory vacuoles and discharge the fluid into the reservoir from where it goes out through the cytostome.

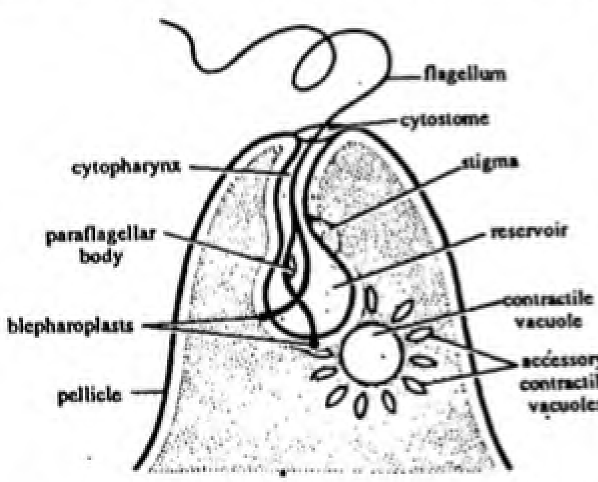

Fig. 2.2 Anterior end of *Euglena.*

Stigma A conspicuous structure in *Euglena* is the red eye spot or *stigma.* This is placed near the inner end of the gullet close to the reservoir. It consists of protoplasm in which clusters of lipid globules containing orange or red carotinoid pigments. The stigma is cup-shaped with a colourless mass of oily droplets in its concavity which functions as a lens. The stigma and paraflagellar body, together form a photoreceptor apparatus.

Paraflagellar body. A small swelling lies either on one root or at the junction of two roots of the flagellum. It is known as *paraflagellar body. Chadefaud* and *Provasoli* have shown that paraflagellar body and stigma together form the photoreceptor apparatus.

Flagellum. A single, long, whip-like flagellum emerges out of the cytostome through cytopharynx. This whip-like process, by its lasting movements, causes the organism to move in water. The flagellum of *Euglena* is also called *tractellum* because it does not propel the body from behind but draws its forward. The flagellum arise from the bottom of the cytopharynx, is forked at the base and is connected by two *rhizoplasts* to the basal granules or *blepharoplasts.* Each blepharoplast is a compact granule that gives rise to a separate filament (*axoneme*), and in most of the species the two axoneme soon unite to form a definite flagellum. In *E. viridis* the flagellum is enlarged at the junction of two axoneme or just behind it to for the paraflagellar body. The paraflagellar body probably contain lactoflavin as sensitiger.

According to some workers, there are two flagella in *E. spirogyra,* one long and the other is short. Each arising from the basal granule located at the base of reservoir. The short flagellum does not extend beyond the neck of the reservoir and is often adharent to the long flagellum giving the appearance of bifurcation.

Each flagellum is cylinderical structure about 0.25u in diameter. It is composed of a longitudinal bundle of microtubular fibres (axoneme) enclosed within a unit membrane which is continuous with the cell membrane. The microtubular fibrils of the axoneme are arranged in a precise pattern, best seen in a T.S. Two microtubules occupy the central position. They are called

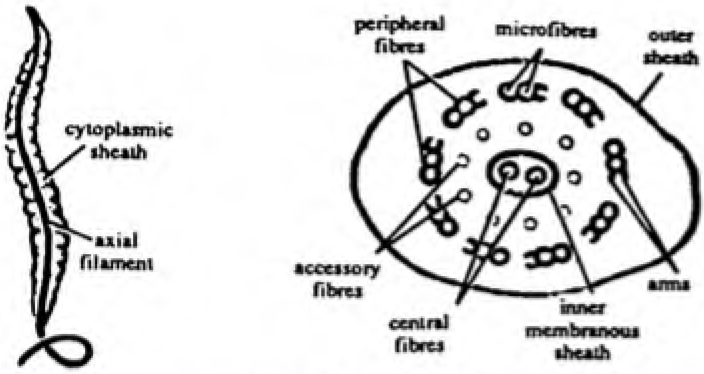

Fig. 2.3 *Euglena*, flagellum & T.S. of flagellum

central fibres and remain surrounded by inner membraneous sheath. The central fibres are surrounded by nine double microtubular fibrils called *peripheral fibres.* Each peripheral fibre is made of two microfibres. One of the microfibres bears a double row of short *arms* or projections all pointing the same direction. The distal portion of flagellum contains numerous minute fibres, known as *mastigonemes*, which project laterally (*Manton, 1959*). Such a flagellum that bears mastigonemes is called *stichonematic type*. Mastigonemes are believed to project rigidly from the flagellum in two rows arranged in the plane of flagellar undulation.

The structure of blepharoplast is similar to that of the centriole found in animal cells. There are evidences which show that basal body contain DNA and may have some power of self-replication.

Cytoplasm. Two types of cytoplasm can be distinguished in *Euglena*, a dense outer layer, the *ectoplasm* and the central mass, the *endoplasm*, which is more fluid. The endoplasm contains nucleus, chromatophore and paramylum bodies.

Nucleus. Euglena has a single oval nucleus laying in a definite position near the centre of the body. There is a distinct nuclear membrane. The nucleus contains a central body known as *endosome* (Syn. *nucleolus, Karyosome*).

Chromatophores. Nearly all species of *Euglena* have small or large coloured bodies called chromatophores. They are present in the form of little plates or discs, sometimes spindle-shaped, band-like or radiating star-like. The number, shape, size and arrangement of chromatophores vary from one species to another. The colour of chromatophore is green due to the presence of green pigment called chlorophyll. The chlorophyll consists of two pigments, the green chlorophyll *a* and a yellowish β carotene.

Under electron-microscope the chromatophore is swollen in the centre where it contains two non-pigmented hemispherical bodies called *pyrenophores.* Attached to one of each are protein bodies called *pyrenosomes.* Each pyrenosome is covered with a *paramylum shell.* The two pyrenosomes constitute a *pyrenoid.* Pyrenoids are associated with the formation of a kind of animal carbohydrate called *paramylon.* Paramylon granules thus produced may be found scattered about the cytoplasm.

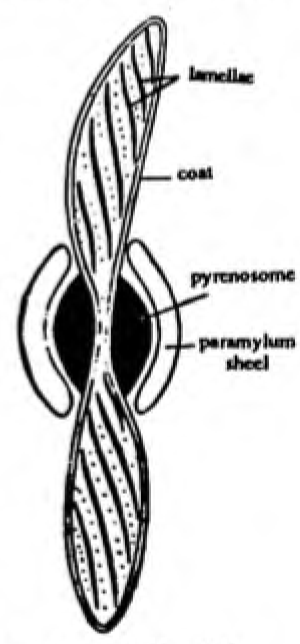

Fig. 2.4 A chloroplast

The chromatophore is surrounded by two membranes. The outer membrane is similar to plasma membrane. The inner membrane is similar to internal membrane system of the chloroplast. The *matrix* or *stroma* contains the chlorophyll-bearing bundles or *thylakoids.* The matrix contains the photosynthetic carbon cycle enzynes, ribosomes and DNA.

Paramylon. Here and there are scattered light bluish-green refractile granules called *paramylon.* It is a polysaccharide similar to starch but it does not give violet colour with iodine solution.

Other endoplasmic organelles. The endoplasm outside the nucleus clearly has a system of double-membranes forming the *endoplasmic reticulum.* Numerous small granules, termed *mitochondria*, are scattered throughout the cell. The mitochondria are important as a location of many of the biochemical reactions of the cell during respiration. *Golgi complex* are abundant but of unknown function. The *ribosomes* also scattered and remain attached to the endoplasmic reticulum.

In some species of *Euglena*, a fine fibril called *rhizoplast*, extends from one of the blepharoplast to a small granule on the nucleus. This connection suggests that the flegellum is under the direct control of nucleus. The flagellum, blepharoplast, rhizoplast and the granule on the nucleus are said to form *infra-ciliary system* or *neuromotor system*.

PHYSIOLOGY

Locomotion

There are two methods of locomotion is *Euglena:*

1. Flagellar movement
2. Euglenoid movement

1. *Flagellar movement.* The process of the flagellar movement is not clearly understood because, except a few, its movements are not easy to observe in most animals. The whip-like movement of flagellum moves the animal forward and at the same time rotates it around the axis. Thus the animal moves forward in a spiral manner at a fair speed of 3.6 mm per minute. Various theories have been put forward to explain the mechanism of flagellar movements in *Euglena.*

Butschli was first to describe the flagellar movement. He observed that the flagellum undergoes a series of lateral movement and in doing so, a pressure is exerted on the water at right angles to its surface. This pressure creates two forces: one directed parallel and other at right angles, to the main axis of body. The parallel force will drive the animal forward and the other force would rotate the animal on its own axis.

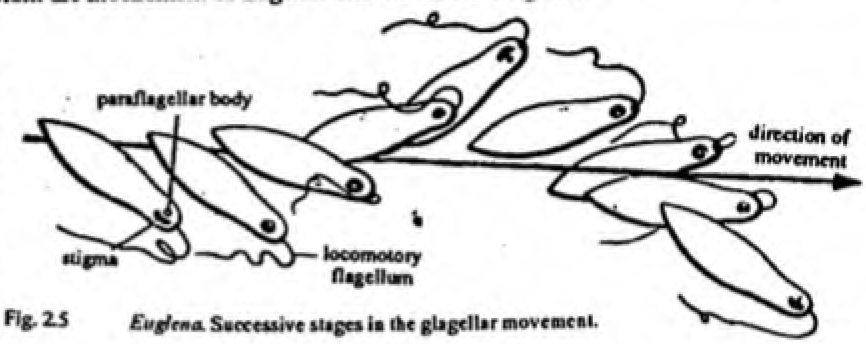

Fig. 2.5 *Euglena.* Successive stages in the glagellar movement.

According to *Gray* (1928), the flagellum beats sideways in such a way that its movement proceeds from one end to other. These waves create two types of forces, one in the direction of the movement and the other in the circular direction with the main axis of body. The first force will drive the animal forward and the later would rotate the animal. The posterior end of body describes a smaller circle than the anterior end while the body is propelled forward through the water like a rotating plane which always remains inclined at an angle of 300 to the axis of movement.

Lowends (1941-43) also studied the locomotion in *Euglena.* His views are a little different from those of *Gray.* According to him, the flagellum is always held backwards during swimming and the movement in it occurs in a spiral manner from base to its tip. The flagellum beats, on an average, at the rate of 12 beats per second with increasing velocity and amplitude.

Krijisman (1952) observed the movement of flagellum under the dark-field microscope. According to him the normal movement of the flagellum is on the lateral side in a whip-like manner due to which it is called *effective stroke* in which the flagellum remains on outer side and moves quickly downwards. After this in *recovery stroke* the flagellum is brought up in a curved and relaxed state. As a result of these movements the animal moves forwards and rotate around its axis.

While the flagellum is moving it must be dissipating energy (*Brokaw*) as a result of work done against the surrounding water. The energy is supplied by ATP (adenosine triphosphate) present in the mitochondria to the blepharoplasts. The function of mastigonemes present on the flagellum is unknown.

Euglena is unable to swim backwards as the direction of motion can not be reversed.

2. *Euglenoid movements* or *Metaboly.* Sometimes a creeping movement is found in *Euglena.* It is brought about by the contraction and expansion of body. A peristaltic wave of contraction and expansion passes over the entire body from anterior to posterior end and the animal moves forward. The body becomes shorter and wider first at the anterior end, then in the middle and later at the posterior end. The contraction and expansion of the body is due to thin, elastic pellicle and the myonemes present beneath it. This is a very slow movement. *Lowends* found that an *Euglena* of (50-64 μ long) travelled at 168 μ.

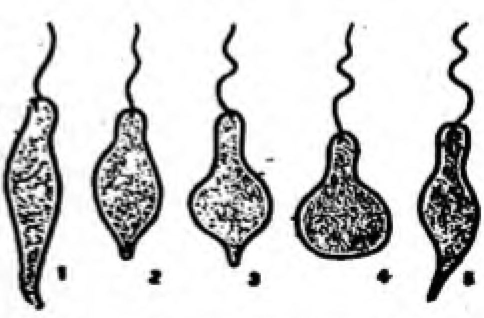

Fig. 2.6 - *Euglena* showing binary fission.

Nutrition

The mode of nutrition in *Euglena* is *mixotrophic* i.e. the nutrition is accomplished either by *holoplytic* or *saprozoic* or by both the modes.

Holophytic or *Autotrophic nutrition.* Although *Euglena* has a mouth (cytostome) and gullet, it is doubtful if any food is ingested. The food is manufactured photosynthetically, as in plants, with the aid of light, carbon dioxide and the chlorophyll present in chromatophores. This mode of nutrition is known as *holophytic* or *autotrophic*. Photosynthesis enables the oxygen and a water molecule to be released, while hydrogen of the water molecule reduces the carbon dioxide present through a series of steps to form carbohydrates and more water. The carbohydrates are stored as a starch-like substance called *paramylum.*

Saprozoic nutrition When the animal is kept in dark for a long time or the chloroplyll is destroyed by treatment with certain drugs, the colourless *Euglena* resulting can continue to live if provided with a medium rich in organic nutrients. This seems to indicate that organic substances in solution are absorbed through the surface of the body, that is, *saprophytic* nutrition.

Myxotrophic nutrition. The euglenae are sometimes holophytic and sometimes saprozoic depending upon the external conditions for maintaining life.

According to recent information, the *Euglena* is *amphitrophic.* It is holophytic in sun light and saprozoic in dark. In the sunlight, it is holophytic but not completely as it needs Vitamin B_{12} or B_1. In the absence of these vitamins it will not multiply. This nutritional versatility is called amphitrophy.

Respiration

Respiration in *Euglena* is *aerobic* i.e. occurs in the presence of oxygen. The exchange of gases takes place through general body surface. Oxygen diffuses into the cytoplasm from the surrounding water and carbon dioxide diffused out. During active photosynthesis in the organism diffusion of carbon dioxide inwards and the output of oxygen mask the respiratory diffusion.

Excretion

Chemical processes keep on taking place in the body all the times, some of which produce materials that are of no use to the animal and may even prove harmful. During the catabolism of amino acid ammonia is formed. It is highly toxic and dissolved in water. This ammonia must be excreted as soon as it is formed. Some of the ammonia is diffused out through general body surface. Some of the ammonia is excreted out by contractile vacuole. The excretory role of contractile vacuole has gained support in the past few years. (*Chaudefaud*). The contractile vacuole is surrounded by specialized granular cytoplasm called *excretory* cytoplasm. Ammonia with large quantities of water first collect in the region of excretory cytoplasm as small droplets as accessory vacuoles which later on fuse to form the contractible vacuole. Periodically, the vacuole reaches its maximum size (*diastole*) and then burst (*systole*) so as to discharge its contents in reservoir, from where waste passes out through the cytostome.

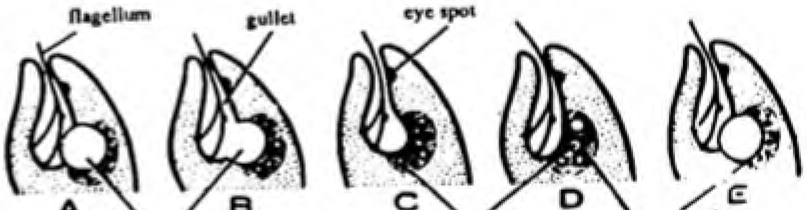

Fig. 2.7 *Euglena* showing pallmella stage.

Osmoregulation

The primary function of contractile vacuole is *osmoregulation* or removal of excess of water from the body. The cytoplasm is denser than the surrounding water and thus has a relatively higher osmotic pressure. The surrounding water constantly enters the body by endosmosis through the pellicle. Moreover, water is also formed in the body during respiration. The excess of water from all over the body flows towards the excretory cytoplasm (described above) and collects in small accessory vacuoles. These water droplets unite to form the contractile vacuole (diastole) and during systole the water is discharged in the reservoir.

Behaviour

Like other protozoans, *Euglena* possesses a good degree of irritability i.e. the power of responding to external stimuli. This

power enables it to avoid unfavourable environmental conditions. While swimming forward rotating and gyrating on its long axis *Euglena* may reach an unfavourable area. When this happens it turns violently usually heading into favourable area again. For this the gyration of the anterior end is suddenly widened and a new spiral path is taken. This behaviour gives the appearence of an animal trying a particular direction and correcting the error, if misled. Thus, such a behaviour is called *trial and error* behaviour, but it is better to call it *avoiding reaction.*

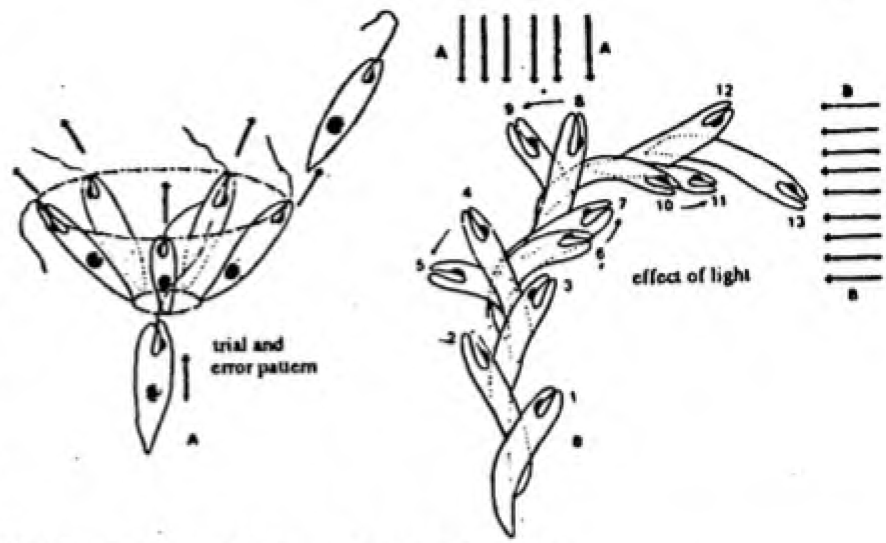

Fig. 2.8 A—Avoiding reaction of *Euglena* and B—Effect of light on *Euglena*.

Reaction to light or phototaxis. *Euglena* is sensitive to light. It swims towards an ordinary light such at that from a window and avoids strong light. The light is preceived only at the anterior end by the specialized eye-spot. This specialization is important since they depend upon photosynthesis for their nourishment. *Euglena* orientates itself parallel to rays of light whenever the paraflagellar body is shaded by the eye spot or stigma. The animal adjusts its position to the direction of light moving either towards or away from it. It is now known after the experiments of *Tchakotine* (1936) that if the stigma is experimentally destroyed by ultraviolet light, the light-reactions disappear.

Euglena gives avoiding reaction to mechanical, thermal and chemical stimuli on a trial and error pattern.

Reproduction

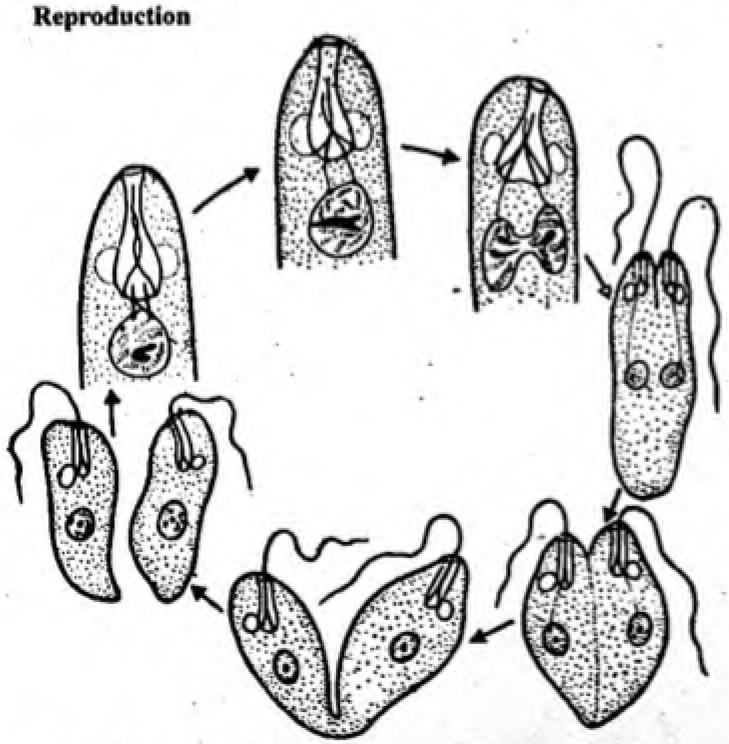

Fig. 2.10 *Euglena* showing binary fission.

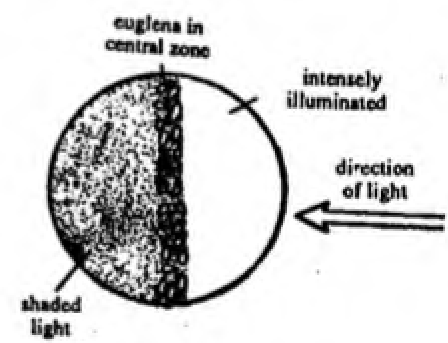

Fig. 2.9 Reaction to light in *Euglena*.

In *Euglena* only asexual reproduction occurs. Sexual reproduction is not reported. The asexual reproduction takes place by longitudinal binary fission and multiple fission. Encystment also takes place.

Longitudinal binary fission. Longitudinal binary fission takes place during favourable conditions. Nuclear division takes place within the nuclear membrane. The chromomeres in the vegetative stage, forms pairs of chromosomes each of which divides longitudinally into two. The endosome becomes con-

stricted into two approximately equal parts. The nucleus before its division migrates from the centre of body to lie just beneath the bases of the flagellum. During nuclear division, duplication of anterior extranuclear organelles such as flagella, blepharoplasts, cytostome, cytopharynx, reservoir, contractile vacuole chromatophores etc. also take place. Soon after this, a longitudinal groove appears at the anterior end and gradually proceeds backwards as a result of which the body of animal is divided longitudinally into two halves. This division is *symmetrogenic* as one daughter is the plane mirror image of the other.

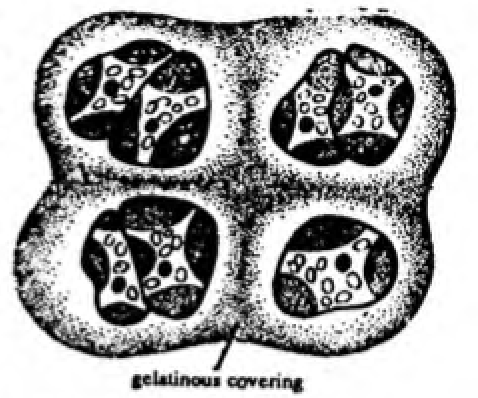

Fig. 2.11 *Euglena showing pallmella stage.*

In some species, it has been observed that the paraflagellar body disappears before the onset of division. In others, the stigma breaks up into small pieces prior to binary fission. According to some workers the flagellum is completely lost and each daughter cell develops its own new flagellum. Often division takes place while the animals are in encysted condition.

Multiple fission and Palmella stage. During unfavourable conditions, multiple fission takes place in *Euglena.* It secretes very rapidly thick or thin cyst within which it divides into several (16-32) daughter euglenae. Sometimes, it loses its flagellum and round up into an alga-like cell in which metabolism continues and reproduction occurs by fission, thus forming extensive green scums on the surface of ponds. This condition is called palmella stage. Later flagella grow in these daughter euglenae which become free and develop into adult.

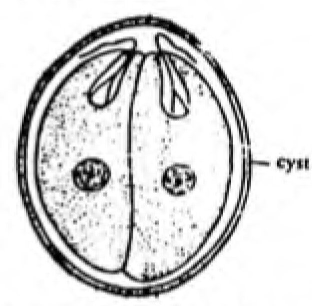

Fig. 2.12 Binary fission in a cyst.

Encystment. This is not a method of reproduction but is a mean to overcome unfavourable conditions. In the process of encystment, the cysts are formed by a special type of yellowish-brown carbohydrates. Their shape is generally rounded and their walls are formed of three concentric layers. During encystment binary fission may occur one or more times. On return of favourable conditions cyst wall breaks, the animal becomes active and emerge from the cyst to lead a normal life.

In different species of *Euglena,* the cyst may be thick, stalked or operculated and the organism lying centrally or eccentrically.

POSITION OF *EUGLENA*

Euglena is considered to be an animal by zoologists and plant by botanists.

Animal Characters. The animal characters of *Euglena* include:

1. Pellicle is made up of protein and not of cellulose as in plants.
2. Presence of cytostome and gullet which resembles similar structures in the relatives of *Euglena* that are distinctly animals.
3. Presence of contractile vacuole.
4. Nutrition is heterotrophic, partial or complete.
5. Utalization of amino acids, pentoses or polypeptides as sources of nitrogen.
6. Reproduction by binary fission.

Plant Characters. The plant characters of *Euglena* are

1. Presence of chromatophore and chlorophyll.
2. Pyrenoid bodies are present.
3. Mode of nutrition is holophytic.
4. Existence of palmella stage.
5. Photosynthesis takes place in sun-light.

The main plant like character is presence of chromatophores and pyrenoids. But these are present only in some species and these can survice even without them. Moreover, the chlorophyll of this organism contains fewer pigments then the chlorophyll of plants. Only few species of *Euglena* are autotrophic and they too only partly. In the absence of light the mode of nutrition becomes saprozoic. During sun light the carbohydrate formed is paramylon which differs from the plant starch as it does not give violet colour with iodine solution. Palmella stage is an adaptation rather than affinity with plants.

Thus it appears that some of the species of *Euglena* are true animal like while few others behave as animal at one time and plant at other time. Its position suggest that we should regard *Euglena* as the intermediate stage in the evolution of plants and animals.

3

TRYPANOSOMA

Ford and *Dutton* (1902) were first to report that *Trypanosoma* was a human parasite and also the causative of 'Gambia' fever: *Kleine* (1909) asserted that tse-tse fly (*Glossina*) was the intermediate host in the life history of *Trypanosoma*.

Trypanosoma belongs to the Order Kinetoplastida which comprises relatively simple forms possessing 1-2 flagella provided with a few accessory kinetic structures. *Trypanosoma* and its relatives constitute a closely knit family of pleomorphic parasites which are of great medical and economic importance. Members of the genus are found in all the classes of vertebrates but are pathogenic only to man and domestic mammals, probably representing recently acquired hosts. The cause of their extreme harmfulness to man and domestic mammals is obscure but may consist in the liberation of toxins. The pathogenic trypanosomes are confined to the tropical countries. They are transmitted from one host to another by blood sucking invertebrates such as insects, mites, ticks and leeches, in whose intestine they undergo a definite cycle of development, requiring a number of days, before they become again infective to vertebrates.

There are two species of *Trypanosoma* found in man. The African human *trypanosomiasis*, known as sleeping sickness, is caused by *T. brucei gambiense* and *T. brucei rhodesiense* are found. The first subspecies is confined to the central and West Africa particularly in Congo and Nigeria. The second subspecies in Rhodesia. The vectors for these trypanosomes are species of blood sucking tsetse fly-*Glossina palpalis* or *Glossina tachenoides*. Another species is *Trypanosoma cruzi*, it is found in South and Central Africa in man and a diversity of mammals, between which it is transmitted by blood sucking bugs, *Rhodnius* or *Triatoma megista*.

The following description is based on the biology of *T. brucei gambiense*.

SYSTEMIC POSITION

Phylum	-	Protozoa
Subphylum	-	Sarcomastigophora
Superclass	-	Mastigophora
Class	-	Zoomastigiphora
Order	-	Kinetoplastida.
Genus	-	*Trypanosoma*
Species	-	*brucei*
Sub species	-	*gambiense.*

Morphology

Shape and Size. *Trypanosoma* is acellular, microscopic animal. The body of adult animal is fusiform or spindle-shaped and is pointed at both the ends. It measures 10-60μ in length and 1-3μ in width. The anterior end tapers gradually and is more pointed than the posterior end and it is well marked by the emergence of the free flagellum.

Pellicle. The body of the organism is surrounded by a thin, elastic, firm and protective pellicle. Due to the presence of pellicle the shape of the body remains constant. The pellicle itself is made up of fine microtubules running spirally around the body of the animal.

Flagellum. *Trypanosoma* bears a single flagellum (uniflagellate) which arises from a minute granule, the *blepharoplast* or

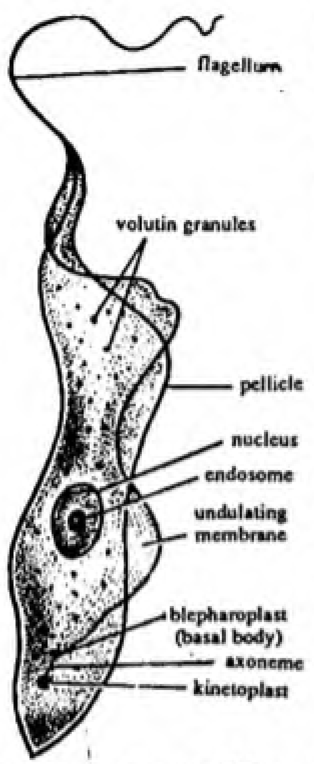

Fig. 3.1 Structure of *Trypanosoma*

basal granule, situated at the posterior end of the body. Just posterior to the blepharoplast, is a small rod-shaped body, the *Kinetoplast* (sometimes erroneously called the parabasal body), which is connected to the blepharoplast by fine fibrils. These two structures usually stain as one. The flagellum extends throughout the length of the body. It remains attached to the body all along its length by means of a thin membrane called *undulating membrane* which is considered as an extension of the cytoplasm in the form of a membrane and then emerges as a free flagellum for a short instances. In life, waves pass into the undulating membrane from the base of the flagellum to its tip. The undulating membrane is said to be an adaptation to movement in a viscous medium i.e. blood. The flagellum and accessory structures are called the *kinetic apparatus*.

In a transverse section the flagellum shows the pattern of 9+2 internal fibres.

Cytoplasm. The cytoplasm is not distinguished into ectoplasm and endoplasm under electronmicroscope. In the cytoplasm there lies a large, rounded or disc-shaped vesicular *nucleus*. It is usually centrally placed but its position varies under different circumstances. In the nucleus lies a large *endosome* or *nucleolus* surrounded by a clear space. Chromatin is either embedded in the endosome or adherent to the nuclear membrane. In the cytoplasm are scattered, greenish refractile particles called *volutin granules* under light microscope. The volutin granules apparently represent reserve nucleic acid. The contractile vacuoles and food vacuoles are altogether absent. Fine structure of *Trypansoma* have been studies by *Vickerman* (1969). Under electronmicroscope, throughout the cytoplasm of the body is a tubular network of rough endoplasmic reticulum. A small pocket or *reservoir* is present at the posterior end of the body. These is no cytostome. A single Golgi-complex is present between the nucleus and the reservoir. A single elongated giant mitochondrion running the whole length of the body. Its cristate may be present or absent depending upon the form and state of the parasite, near the basal granule and within the mitochondrion is a small mass of DNA, till recently called kinetosome and parabasal body.

Polymorphism in *Trypanosoma*

Four forms of trypanosomes have been recognised on the basis of the position of kinetic apparatus. These are as follows:

1. *Leishmania* or *Amastigote*. These are round or oval forms with a nucleus, blepharoplast and kinetoplast. The flagellum remains embedded in cytoplasm i.e. it does not come out of cytoplasm.
2. *Leptomonad* or *Promastigote*. Body is elongated. The kinetic apparatus is anteriorly placed. The flagellum is short and unattached.
3. *Crithidia* or *Epimastigote*. Body is elongated and the blepharoplast and kinetoplast are situated anterior to the nucleus. Free flagellum and inconspicuous undulating membrane are present.
4. *Trypanosome* or *Trypomastigote*. It has the structure with blepharoplast and kinetoplast situated at the posterior part of body. Flagellum and undulating membrane are conspicuous.

The crithidial form occurs only in the invertebrate host i.e. tsetse fly.

PHYSIOLOGY

Locomotion

The locomotion is performed by the wavy movements of the undulating membrane and by the flagellum. The whole body also produces waves for locomotion.

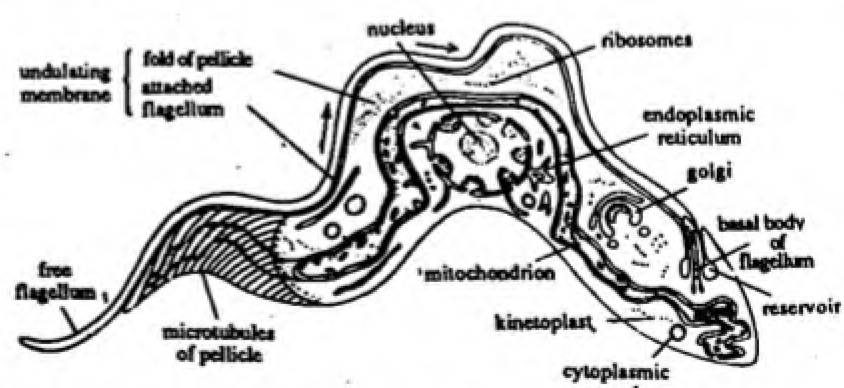

Fig. 3.2 *Trypanosoma* seen under electron microscope

Nutrition

Food must be absorbed from the blood since no mouth is present. The nutritional requirements have been studied in bacteria-free culture media and are quite complex probably as a result of adaptation to the special habitat. Ascorbic acid and hematin have been shown to be essential growth factors. Pinocytosis has been observed in the reservoir.

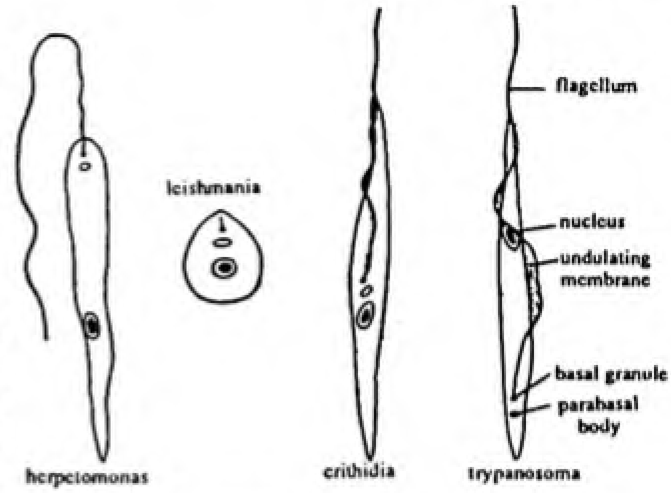

Fig. 3.3 *Trypanosoma* showing polymorphism.

Respiration

The gaseous exchange takes place by diffusion through the pellicle. The animal is *aerobic* takes oxygen from surrouding medium. Oxygen consumption increases with an increase in temperature and glucose content of blood. With the increase in temperature and glucose content of blood. With the increase of antibodies in blood, the rate of oxygen consumption is reduced. As a metabolic activities CO_2 is formed which goes out by diffusion.

Excretion

The chief nitrogenous waste product is ammonia. It is eleminated by diffusion.

Osmoregulation

Since the cytoplasm of *Trypanosoma* is isotonic with the blood plasma, hence less fluid is absorbed and the animal has no problem of osmoregulation. Thus the contractile vacuole is absent.

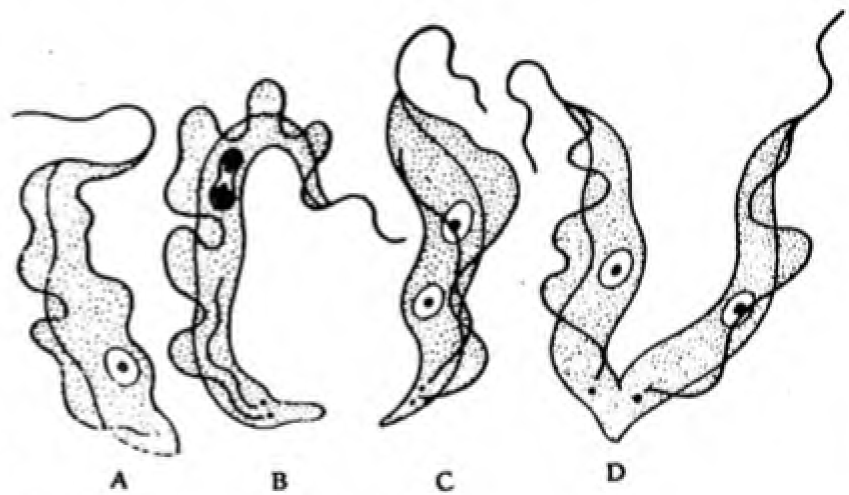

Fig. 3.4 *Trypanosoma* stages in binary fission

Reproduction

In *Trypanosona* only asexual reproduction occurs by *binary fission*, and most commonly it divides longitudinally. Division is thus said to by *symmetrogenic*, that is, producing mirror-image daughter cells. During binary fission, the blepharoplast divides first and then the kinetoplast. A new flagellum begins to grow out along the margin of undaulating membrane. The nucleus divides mitotically into two daughter nuclei. Finally the body splits mid-longitudinally, from anterior to the posterior end, forming two daughter trypanosomes. Thus one daughter individual retains the old flagellum while the other a new one.

The sexual reproduction is unknown in *Trypanosoma*.

LIFE CYCLE

Trypanosmona is a *digenetic* parasite which completes its life-cycle in two hosts, man and tsetse fly. The man serves as primary host and tse-tse fly as secondary host or vector host. Besides the mammals, such as cattles, antelopes, pigs etc. act as reservoir host where the parasite lives until the appropriate vertebrate host is reached.

Life-cycle in man

The parasite get entry into the blood of man with the saliva of an infected tsetse fly *Glossina palpalis* when the fly sucks

the blood of man. The saliva contains anticoagulant to prevent the clotting of blood. The trypanosomes, which initiate infection in man, are in the *metacyclic forms* which devoid of free flagella. Soon the metacyclic forms become transformed into the *long slender forms*. They swim freely in the blood and multiply actively by longitudinal binary fission. As their number is increased the host produces antibodies which prevernts glycolysis so that the inactive mitochondrion becomes active (by the appearence of cristae and production of enzymes). Now the parasites stop multiplication and shrink to a *short-stumby forms* via an *intemediate form*. Ovoid *leishmania forms* are produced in liver, spleen and lungs of the host. These are probably latent forms ment for replacing the losses which occur in the blood of host. During the period of decrease activities the short and stumpy forms, which have great power of resistance, survive the period of depression and the rest die. These short and stympy forms now require the secondary host for further development.

Life cycle in tsetse fly

When tsetse fly sucks the blood of an infected man, the blood carries trypanosomes to the intestine, where they survive the action of digestive juices. The short stumpy form are charged to long slender forms and undergo multiplication by longitudinal binary fission and forms numerous slender froms after about 10-15 days. After several more days the trypanosomes make their way to the salivary gland of tsetse fly. Firstly they reach the labial cavity and hypopharynx and thence they enter into the salivary glands, where they become attached to the cells in the glandular part and then *crithridia forms* are produced. The crithidia forms are characterized by a short flagellum and undulating membrane. The flagellum and undulating membrane do not extend in the hinder part of the body. The blepharoplast and kinetoplast lying in the middle of the body just above the nucleus. The crithidia forms multiply while attached to the gland wall and transfer into free-swimming *metacyclic forms*. In metacyclic forms the kinetic apparatus again moves at the posterior end of the body. The tsetse fly (*Glossina*) becomes infective 20-34 days after sucking the blood i.e. the parasites complete the reproductive cycle within 20-34 days with a temperature between 75°F-85°F. The metacyclic forms are infective stage and pass down through the ducts and hypopharynx. When the tsetse fly sucks the blood of man, along with saliva, the metacyclic forms enter the blood stream of man and starts cycle.

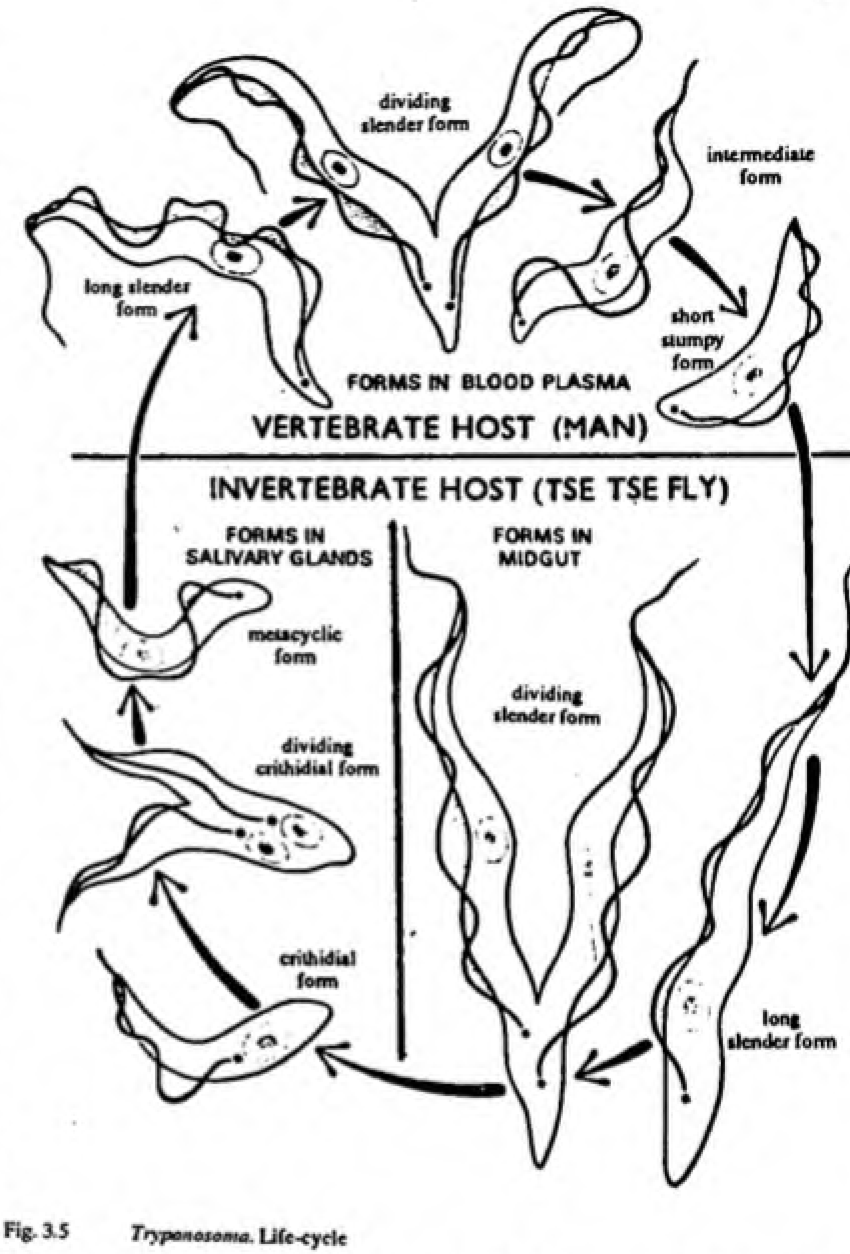

Fig. 3.5 *Trypanosoma*. Life-cycle

✓ DISEASE

The bite of infected fly in usually marked by a dark red button-like lesion forms around the wound which in followed by local itching and irritation. The swelling is known as *trypanosome chancre*. While the parasites are in blood stream, the person

feels headache, fever and general lethargy. Penetration of parasites into the lymphatic glands leads to swelling of spleen, liver, glands lymph etc. With the entry of parasites into cerebrospinal fluid, the patient becomes progressively more lethargic, anaemic and weak finally the patient loses consciousness and sleeping sickness goes to a fatal end.

TREATMENT

Two drugs, *Bayer 205* (also called *Antrypol, Germanin* or *Suramin*) and *Pentamide* or *Lomidine* are now widely used in the early stages of infection (*Trypanosomiasis*). Previously arsenic and antimony compounds were used, now-a-days they are rarely used except for late stages when the parasite have invaded the nervous system.

CONTROL MEASURES ✓

The following measures are suggested to control the African human trypanosomiasis:

1. Kill the tsetse fly with suitable insecticides such DDT.
2. Clear forests and bushes around towns and villages. This will eradicate tsetse flies as the flies take the shelter of trees or bushes during the hot periods.
3. Kill the wild animals that serve as an inexhaustible reservoir of trypanosomes. But it seems impracticable at present.
4. Human population from the endemic areas may be isolated.
5. A single intramuscular injection of 4 mg/kg of pentamidine remains effective for about six months against the disease.

4

AMOEBA PROTEUS

Amoeba is the simplest living organism, which can perform all its life-activities, such as locomotion, nutrition, digestion, excretion, respiration, reproduction etc. in a single cell. It was first discovered by *Von Rossel Rosenhof* in 1755. *H.I. Hirschfield* (1962) has provided a detailed account of its biology.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Subphylum	-	Sarocomastigophora
Superclass	-	Sarcodina
Class	-	Rhizopodea
Subclass	-	Lobosia
Order	-	Amoebida
Genus	-	*Amoeba*
Species	-	*proteus*

Habits and habitat

Amoeba proteus lives in fresh water ponds, pools, ditches and streams having green plants. It is also found in damp soil. *Amoeba proteus* name is derived from two Greek words (Gr. *amoeba* = change; *proteus* = a mythological sea-god, who could change its shape) because it always changes its shape.

Culture

Amoeba may be obtained for laboratory purpose from a variety of places such as organic ooze from decaying vagetation or the lower surface of the lily pads.

Culture of *Amoeba* can be prepared in laboratory. Place some pond water, mud and leaves in 100 ml of water containing a few wheat gains. Amoebae will appear after a few days. To make a pure culture, boil 4-5 grains of wheat in 100 ml of distilled water for about 10 minutes and cool for a few days. To this solution add some amoebae from the previous culture and cover with glass plate. In about 10 days many amoebae will be formed in this culture.

Morphology

Shape and size : Amoeba is unicellular and can be seen clearly with the help of a microscope. It appears as a colourless, transparent and gelatinous mass. Its shape keeps on changing because of presence of many finger like process, the *pseudopodia.* The size varies from 0.2 - 0.3 mm. in diameter. Some larger forms measure 0.5 mm. in diameter, being just visible to the naked eyes as tiny white speaks.

Plasmalemma. The plasmalemma is a very thin, invisible, elastic external membrane which bounds the cytoplasm. It measures 1-3 μ in thickness. The membrane is selective permeable as water and some small molecules can pass freely across it in both the directions, but larger molecules can not pass through. Under electron microscope it is trilaminar structure, consisting of two, darkly stained, layers separated by a clear layer. Each dark layer is composed of mucoproteins and the light layer of lipid (bimolecular layer). The plasmalemma externally posses numerous, ridge-like extensions, the *microvilli.* Zoologists believe that

these have adhesive properties and serve to bind the animal to the substratum.

Cytoplasm. The cytoplasm is differentiated into an outer thin cortical layer called *ectoplasm* and an inner medullary mass called *endoplasm.*

(i) *Ectoplasm.* The ectoplasm forms the outer and relatively firm layer lying just beneath the plasmalemma. It is thin, non-granular and almost transparent. It is slightly thicker on the advancing side of the body and at the tips of pseudopodia where it forms the *hyaline cap.*

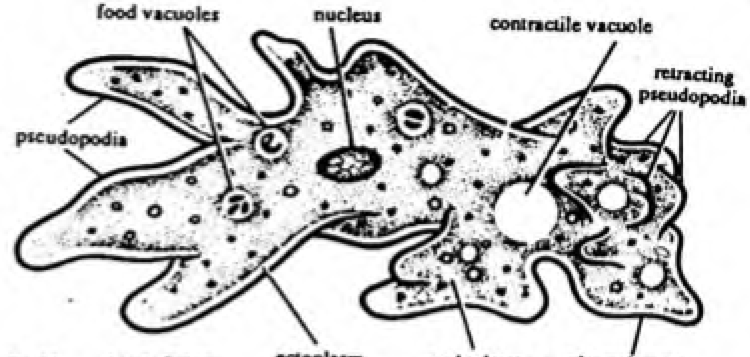

Fig. 4.1 Amoeba Proteus.

(ii) *Endoplasm.* It is less fibrous and more fluid zone of granular cytoplasm. It occurs in two colloidal states (*Mast*, 1926). The peripheral viscid or *gel* state called *plasmagel* and the central flowing or *sol* state called *plasmasol.* Modern studies have proved that the ectoplasm is gel and the endoplasm is sol state of cytoplasm. The endoplasm shows distinct streaming movements, called *cyclosis.*

Nucleus. Amoeba has a single, disc-like or biconcave nucleus. It is usually located in the central part of plasmasol. It is highly granular and, therefore, refractive to light. The nucleus has a firm nuclear membrane which is double and intercepted by pores. Electron microscope studies show a honey comb layer under bilayered nuclear membrane. The nucleoplasm contains few nucleoli and about 500 small spherical chromosomes.

Contractile Vaculole. Lying near the nucleus is a bubble-like spherical body, which is known as contractile vacuole. At regular intervals, it moves to the surface, where it contracts and discharge the water and waste products into the surrounding water. Thus it is *osmoregulatory* in function. The contractile vacuole is bounded by a delicate elastic *condensation membrane.* It is surrounded by many vesicles and mitochondria. Its position is not fixed due to streaming movement of the cytoplasm.

Food vacuoles. A number of spherical food vaculoes small and large, containing food and water in various phase of digestion occur in the endoplasm. These are not permanent structures, but are formed when *Amoeba* ingest food. They disappear with the egestion of undigestible food from the body.

Water globules or *vacuoles.* Innumerable water vacuoles are scattered in the endoplasm. They are colourless, transparent and non-contractile. Their significance is not well known.

Other organelles. Under electron-microscope the endoplasm shows various organelles such as *endoplasmic reticulum, mitochondira, Golgi-complex, lysosomes* and *ribosomes.* Thin filamentous microfibrils are also present in endoplasm. Besides above organelles numerous minute, regularly shaped crystals called, *biurets* and *triurets* are present.

Polarity. Although the animal is shapeless but *Amoeba* is considered to have a definite polarity i.e. it has definite anterior end and posterior ends. The anterior end possesses pseudopodia while the posterior end in marked by a wrinkled region, called *uroid.*

PHYSIOLOGY

Locomotion

Amoeba moves from one place to another to capture its food-material and other organisms by forming the temporary finger-like projections called pseudopodia (Gr. *pseudo* = false; *podium* = foot). These pseudopodia are formed at any part of the body. The characteristic irregular movements found in *Amoeba* are termed as *amoeboid movements.* The pseudopodium is formed by pushing out an enlargement of ectoplasm so as to form a blunt projection. The granular endoplasm than flows in it. As a result of which *Amoeba* moves forward in the direction of pseudopodium. This method of pseudopodial formation is called *profluent type by Hyman.* When several pseudopodia are formed by this method it is called *lobose type* and pseudopodia as *lobopodia.* In some small forms, the lobopodia are formed by *eruptive method.* Here the pseudopodia are formed by bursting out of ectoplasm

and endoplasm. Sometimes several pseudopodia are formed at the start but usually one survive, which becomes larger and effective, while others disappear. Several theories have been put forward about the formation of pseudopodia. These theories are as follow:

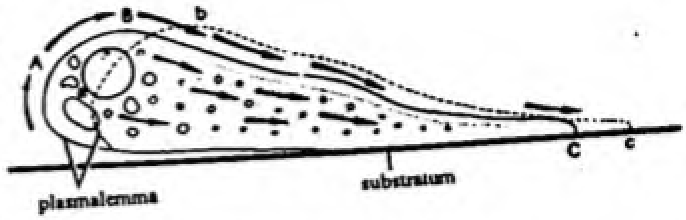

Fig. 4.2 Amoeba verrucosa showing rolling movement

1. *Adhesion Theory.* According to this theory, amoeboid locomotion is brought about by the force of adhesion between the cytoplasm and the substratum. Just as a drop of water, which spreads irregularly on an uneven glass plate. It was thought that *Amoeba* moved irregularly. Due to adhesive properties pseudopadia generally grow in the path of adhesion. When the surface is clear, adhesion is more perfect, and when it is greasy, adhesion is less suitable. This theory is not satisfactory and does not hold good as the pseudopodia are sometimes given out independently even without any contact with any surface.

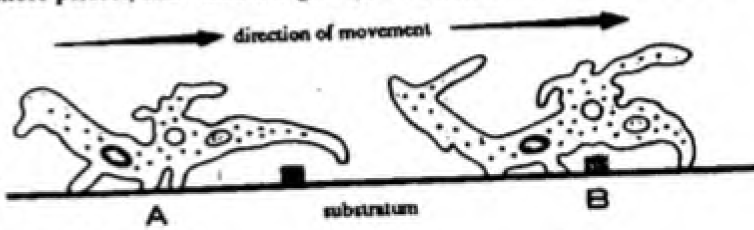

Fig. 4.3 Walking Movement

2. *Rolling movement Theory.* This theory was proposed by *Jennings* (1904). If a particle of carmine is placed on the surface of *Amoeba verrucosa*, it is seen that the particle flows forward, rolls over the anterior edge, then it stops on substratum until the entire animal has passed over it, then the particle move upwards at the posterior end and comes on the upper surface and moves forwards. *Jenmnings* though that the movement of particle was due to streaming movement of cytoplasm which made the body to roll and move ahead. This theory is also called *Jemning's contraction theory.*

   However, there are two objections to this theory:

   (a) *Jennings* performed this experiment on *A. verrucosa* only in which pseudopodia are absent. So that this theory could not be apply to *A. proteus.*

   (b) He was unable to explain, with certainty, the locomotion of contractile substances, which are responsible for forward movement.

3. *Surface - tension Theory. Berthold* (1886) proposed that constant internal tension forces the cytoplasm of *Amoeba* to shoot out from its surface in the form of pseudopodium whenever surface tension suddenly lowers due to local effects. This theory has been supported by *Rhumbler* and *Butschli* (1898). Surface tension does exists on a fluid surface, but its existence upon the surface of plasmalemma of *Amoeba* is doubtful. Thus this theory is not supported now-a-days.

4. *Walking movement Theory.* This theory was proposed by *Dellinger* (1906). He observed *Amoeba* from the side and found that locomotion was a walking process. These movements start by putting out one pseudopodium and then followed by another. On making forward movements pseudopodium is projected out, which takes hold and afterwards contracts. During locomotion, the main part of body remains lifted from the substratum and supported on tips of pseudopodia. Thus *Amoeba* virtually walk on pseudopodia just as the animals move on their legs. *Dellinge* pointed out that *Amoeba* can walk on ceiling as well as floor.

   This theory is also called *Dellinger's contraction Theory.* This theory is unable to explain how the pseudopodia are formed.

5. *Sol-gel Theory.* This theory was first proposed by *Hyman* (1917). Later it was supported by *Pantin* (1923-26) and *Mast* (1925). This is the most acceptable theory now-a-days. According to this theory, the pseudopodia are formed by change of cytoplasm from gel to sol and sol to gel.

   According to *Mast* amoeboid movement is brought about four process :

   (i) Plasmalemma attaches to the sbustratum.

   (ii) Plasmasol moves in the direction of locomotion and comes out by rupturning the plasmalemma at the weakest point. In this newly formed pseudopodium, the plasmasol now changes into the plasmagel due to which a strong gelatinous

tube is formed in pseudopodium.

(iii) At the same time, the plasmagel of hinder end keeps on changing into the plasmasol. This sol flows towards the newly formed pseudopodium so much so that the whole of body cytoplasm comes into it.

(iv) Now the plasmagel tube contracts and the body moves forward. Soon after this, a new pseudopodium is again formed in this direction and all above processes are performed repeatedly due to which *Amoeba* moves forward.

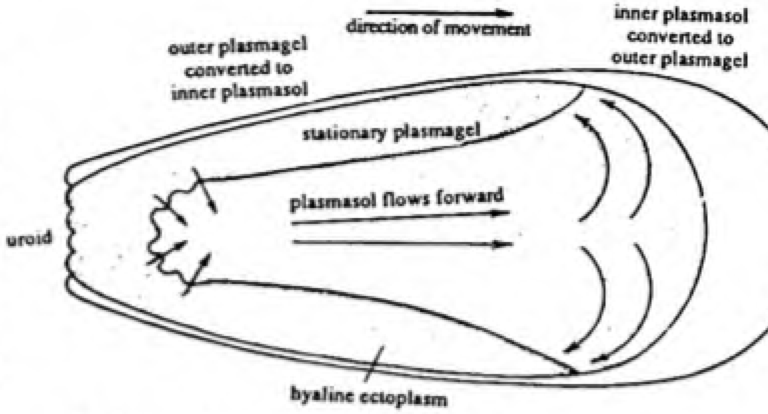

Fig. 4.4 Amoeboid movement after 'sol and gel' theory

6. *Folding and unfolding Theory.* This theory is proposed by *Goldacre and Lorch* (1950). According to them, "There is no doubt that gelation and solution of cytoplasm occur, but it is unlikely that contraction upon gelation would supply the force capable to moving an *Amoeba*." They state that all proteins gelate when their molecules unfold and the solate when their molecules fold. In the fluid endoplasm the protein molecules lie folded compactly, these molecules unfold at the tip of the advancing pseudopodia to form a layer of straightened and attached molecules. Posteriority the protein molecules contraction force. In *Amoeba* the contraction is confined towards the posterior side which forces the contracted proteins towards the anterior end. They compared contractibility in amoeboid movement with that found in muscle-fibres. It is supposed that the energy for the movement of *Amoeba*, folding and unfolding of protein molecules is provided by *adenosine triphosphate* (ATP).

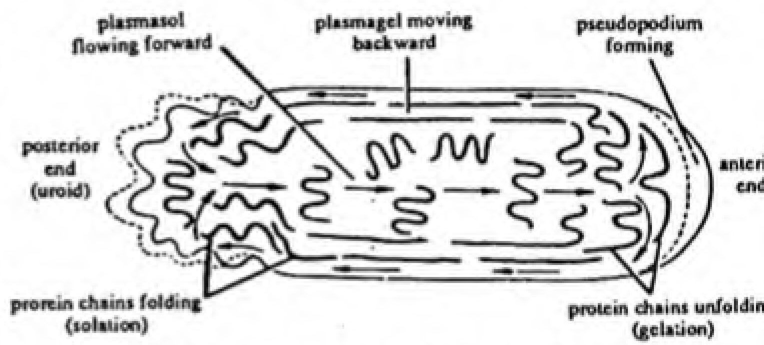

Fig. 4.5 Amoeboid movement after 'folding and unfolding' thoery.

7. *Fountain-zone contraction Theory. Allen* (1962) found that on molecular level, amoeboid movement is actually a type of slow contraction similar in many ways to muscle contraction. Endoplasm is regarded to contain long chains of protein which contract at the anterior end. The endoplasm (sol) chains are in contracted state. The protein chains become extended at the posterior end, where the ectoplasm is liquified during its conversion to endoplasm. Thus according to this theory, the body of *Amoeba* is virtually pulled forward by the contraction at the anterior end.

8. *Contraction - hydraulic Theory. Rinaldi and Jahn* (1963) has supported the theory proposed by *Mast* in an improved form. According to them the contraction of posterior plasmagel is responsible for hydraulic pressure on plasmagel. The resistance to the pressure is least anteriorly. The plasmongel always remains under-continuous tension and localized reduction in the elastic strength is responsible for the formation of pseudopodium.

NUTRITION

Amoeba can not prepare its own food it requires ready-made organic substance for food. Such a mode of nutrition in which solid food particles are ingested is called *Holozoic or Zootrophic*. Its food consists of micro-organisisms such as bacteria, diatoms, other flagellate or ciliate protozoans, minute aquatic plants and mosses. *Amoeba* is, thus *omnivorous* in diet. The process of nutrition is studied under following steps:

(1) ***Ingestion.*** No definite mouth or organelles for ingestion of food particles are present. The food is captured by pseudopodia. Pseudopodia are formed at the points, where the food comes in contact with the surface of the body. According to *Rhumbler*

(1930) following methods of ingestion are employed according to nature of food particles :

(a) *Circumvallation. Amoeba* has to produce many pseudopodia for ingesting a motile food particle like ciliates and flagellates. When it approaches near food-particle the part immediately in line with it stops moving, and pseudopodia form a cup-like structure, the *food-cup* around the food-particle. The rim of food-cup narrows and soon closes on the other side of food-particle. The food-particle, thus, gets into the body. Alongwith food-particle a droplet of water is also engulfed. This water droplet surrounds the food-particle and forms the *food vacuole.* The food vacuole is bounded by plasmalemma.

(b) *Circumfluence.* This method is applied by *Amoeba* when the prey is less-active or motionless. It extends its pseudopodia around the organism and envelops it completely with cytoplasm. The enclosing of the captured organism results in the formation of food vacuole which gets slowly into the cytoplasm.

(c) *Invagination.* In this method the ectoplasm and plasmalemma invaginates into the endoplams to form a small canal as soon as it comes in contact with the food. Later the food particles slips into the tube along with a little water and the mouth or opening of the tube is then closed.

(d) *Import.* In this method, the food itself embeds into the cytoplasm of *Amoeba* as soon as it comes in its contact. Thus *Amoeba* has not to make any special effort to ingest the food in this method.

(2) ***Digestion.*** The digestion is intra-cellular and takes place in the food vacuoles. The lysosomes, which contain digestive enzymes fuse with the food vacuoles and digestion of contained food organism slowly proceeds. The digestions is first carried in acidic medium and latter in alkaline medium. The digestion of starch, protein and fats takes place respectively with the help of *amylase, protease* and *lipase* in the alkaline medium.

(3) ***Absorption and assimilation.*** The digested food, minerals and water are absorbed by the protoplasm and circulate in it. The amino acids are built up to form living protoplasm. Sugars, fatty acids and glycerols provide energy and are also synthesized into storage products, like glycogen and fats.

(4) ***Egestion.*** After digestion, the undigested food can be expelled out from any part of body because there is no definite aperture or *cytopyge* for this purpose. The food vacuoles are shifted backwards and finally come in contact with plasmalemma at the posterior end. The plasmalemma ruptures at this point and the undigested food goes out as the animal moves ahead. The plasmalemma soon gets repaired to prevent the outflow of cytoplasm.

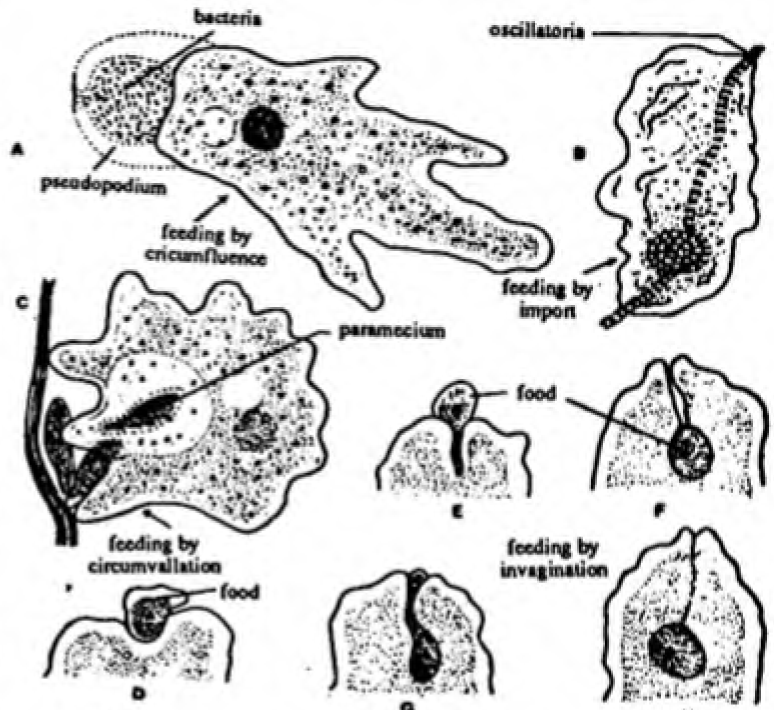

Fig. 4.6 Ingestion of food by A—Circumfluence B—Import C—Circumvallation; and D—H-Invagination.

RESPIRATION

Respiration in *Amoeba* is aerobic and takes place through general body surface by diffusion, as there is no special respiratory organ or pigments. Oxygen constantly diffuses into the cytoplasm for its concentration in water is always higher than in the body. This oxygen is used in the oxidation of food-stuffs like carbohydrates, fats and even protein to obtain energy. As a result water, carbon dioxide etc. are formed. The carbon dioxide is diffused out in the surrounding water.

EXCRETION

The nitrogenous waste products consist of compounds of ammonia such as urea and occasionally urates. In the dissolved state, they diffused out from the general body surface. It has been recently claimed that the cystals called *biurets* or *bipyramidal* and *triurets* or *tripyramidal*, found in cytoplasm. These crystals are formed of an excretory substance, *carbonyl diurea*. Some of these crystals are removed with undigested material and some are redissolve and diffused out. Contractile vacuole also helps removing liquid exertion to some extent.

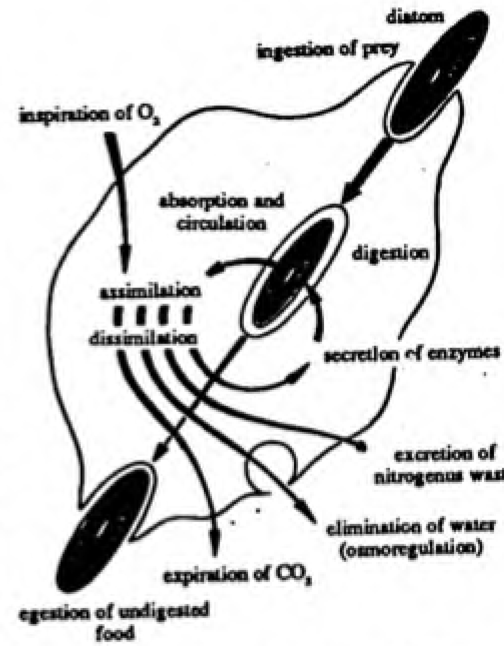

Fig. 4.7 Diagramatic representation of various metabolic process going on in a living *Amoeba*.

OSMOREGULATION

Since the cytoplasm of *Amoeba* is hypertonic to the surrounding medium, water continuously enters the body by endosmosis. Some of the water also comes in cytoplasm from food vacuoles. If all this water is allowed to accumulate, the body will soon swell and burst. So to regulate the amount of water in cytoplasm the excessive water is eliminated out from the body and this is brought about by the contractile vacuole. The contractile vacuole regularly pumps out excess water. Its working is divisible into two phases - diastole and systole. The growing phase up to the maximum size reached is called *diasotle* and the collapsed condition is referred to as *systole*. How the water is forced out of the protoplasm into the vacuole is not known. There are three theories for the growth of contractile vacuole.

(i) *Osmosis Theory.* According to this theory, the water passes into the growing vacuole by the simple process of osmosis.

(ii) *Filteration Theory.* According to this view the water filters through the vacuolar membrane into the vacuole because of the hydrostatic pressure of the endoplasm.

(iii) *Secretion Theory.* According to this theory the water is first absorbed in the vacuolar membrane and then secreted into the vacuole.

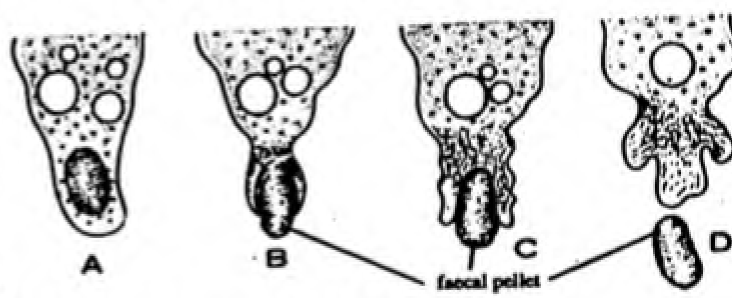

Fig. 4.8 *Amoeba* showing egestion of undigested food

It has been found that the growth of the vacuole takes place in spurts and not steadily. From this it is concluded that the fluid enters the vacuole by the fusion of similar smaller vacuoles. On attaining the maximum size (diastole) the contractile vacuole migrates to the surface until it reaches the plasmalemma which subsequently bursts discharging the contents (systole).

It is possible that the expelled water may contain some excretory products, but there is no experimental evidence to show such function.

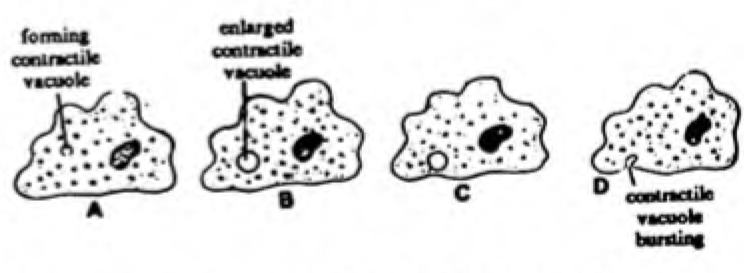

Fig. 4.9 *Amoeba* showing stages in the contraction of contractile vacuole

BEHAVIOUR

Amoeba responds to both external and internal stimuli. Responses of *Amoeba* to the stimuli constitute *behaviour or irritability*. *Amoeba* responds to stimuli mainly by locomotary behaviour. When stimulated, it either continues advancing towards

the source of stimulation (*positive response*), or moves away from it (*negative response*). Its responses are as follows:

1. *Reaction to mechanical stimuli* (*Thigmotamis or Thigmotropism*). On coming in contact with a solid object, *Amoeba* generally avoids it by moving in different direction by the formation of new pseudopodia. This is an example of negative response to touch. A floating *Amoeba*, on the other hand, responds to touch in a positive way. As soon as any of its pseudopodia comes in contact with a floating surface it spreads and adheres to the surface, and soon starts creeping on the surface.

2. *Reaction to light* (*Phototaxis or Phototropism*). *Amoeba* avoids both direct sunlight as well as total darkness (negative response). It responds positively to diffuse or normal light.

3. *Reaction to temperature* (*Thermotaxis or Thermotropism*). It avoids higher temperature as well as low temperature. The optimum temperature ranges between 20-25°C, Beyond 30°C it ceases all the activities.

4. *Reaction to chemical stimuli* (*Chemotaxis or Chemotropism*). *Amoeba* reacts negatively to all such substances (like acids, alkalies, sugars etc.) which are not found in pond water.

5. *Reaction to gravity* (*Geotaxis or Geotropism*). It has been suggested that amoebae are positive to the force of gravity as they drop to the bottom of the container.

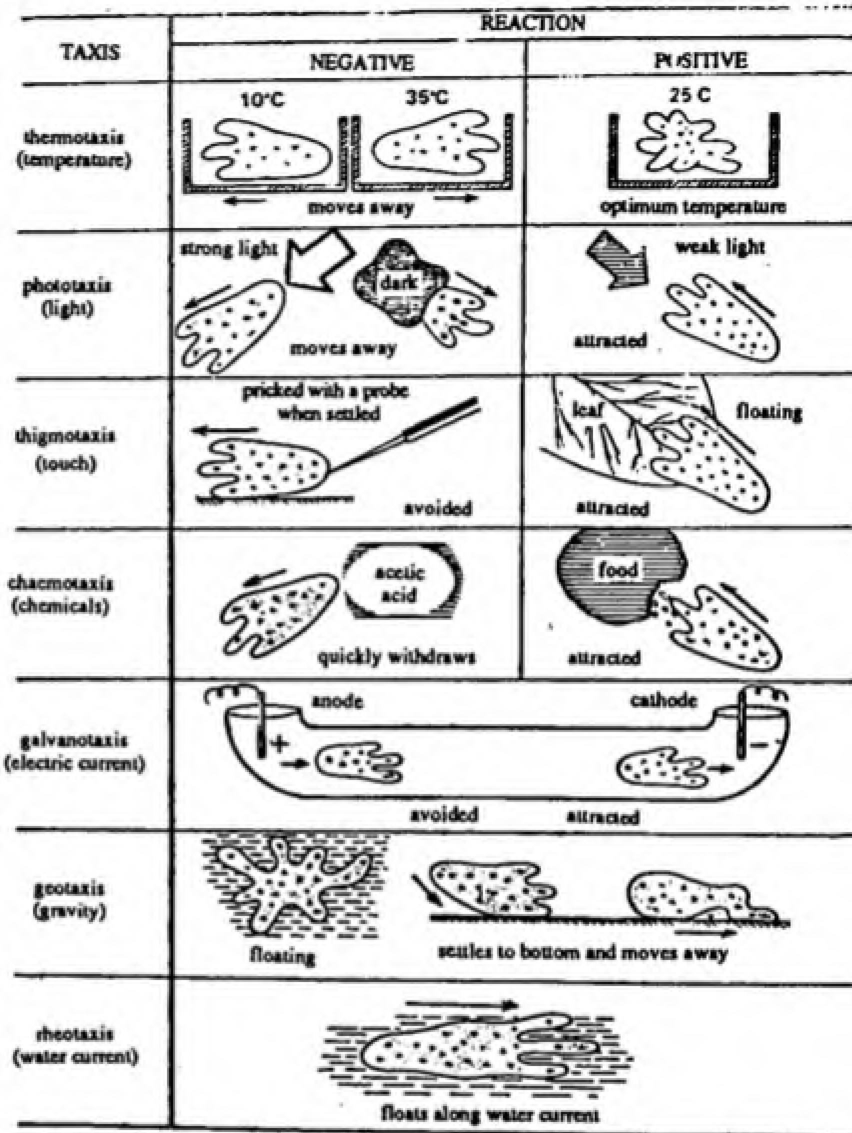

Fig. 4.10 *Amoeba* showing reaction to various stimuli.

6. *Reaction to the electric current* (*Galvanotaxis or Galvanotropism*). When mild and steady electric current is passed through the water containing amoebae, they move towards the cathode. A strong electric current is fatal.

7. *Reaction to water current* (*Rheotaxis or Rhotropism*). When floating freely in water the amoebae place in line with the water current i.e. they are positive to it.

8. *Reaction to hydrostatic pressure* (*Barotaxis*). When the hydrostatic pressure is increased, the rate of movement is decreased. Further increase forces them to stop their movement completely.

REPRODUCTION

Amoeba has only asexual reproduction. It takes place by following ways :

1. ***Binary Fission.*** This is the commonest and simplest method of reproduction in *Amoeba*. In this, the entire body divides,

like an ordinary cell, into two daughters by mitosis. It occurs during favourable conditions and takes about half an hour at 24°C. For long such a division was thought to be amitotic, but it has now been shown that the *Amoeba* divides mitotically. Such a mitosis is called *Cryptomitosis* which, however, involves the usual four phase (Prophase, metaphase, anaphase and telophase).

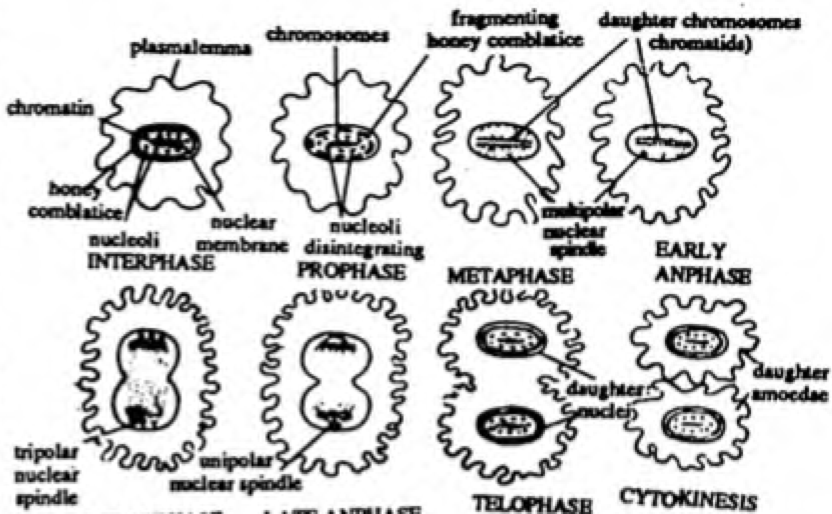

Fig. 4.11 *Amoeba* showing binary fission

(i) *Prophase*, During prophase the body becomes spherical, studded with short, blunt pseudopodia and very small sized spherical chromosomes make their appearance. Nuclear membrane and endosome remain intact, working of contractile vacuole slows down. The prophase lasts for 10 minutes.

(ii) *Metaphase*. The chromosomes arrange at the equator of the spindle-shaped nucleus to form a *metaphase plate*. The nucleus becomes larger endosome breaks up into pieces. The chromosomes segreagate into two sets. The metaphase lasts for about 4-6 minutes.

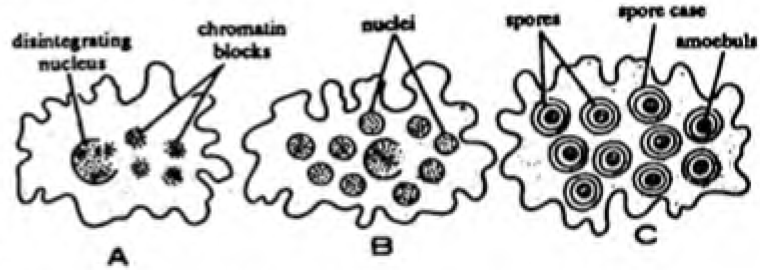

Fig. 4.12 *Amoeba* showing sporulation

(iii) *Anaphase*. It is marked by a change in the external form, the pseudopodia become course and thick. The two sets of chromosomes move apart almost entirely by the enormous elongation of the inter-chromosomal region. Anaphase lasts for about 10 minutes.

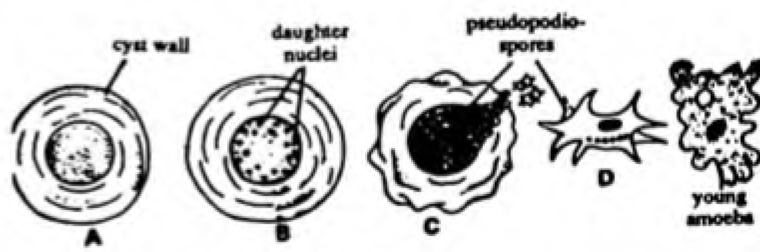

Fig. 4.13 Amoeba showing encystment & multiple fission

(iv) *Telophase*. In telophase, pseudopodia assume normal shape; the body first elongates, then constricts in the middle. Two sets of chromosomes reach their poles where each set in enveloped by a nuclear membrane. The construction finally divides the *Amoeba* into two daughters each having a daughter nucleus. The contractile vacuole is retained by one of the daughter, the other one acquires a new vacuole. The telophase takes 8 minutes. Daughter amoebae may begin to divide after 24 hours.

2. ***Sporulation***. It occurs when the conditions become unfavourable. Before the conditions become unbearable, the nucleus divides repeatedly and mitotically into nuclei without the breaking up of the nuclear membrane. Such a nucleus which contains several sets of chromosomes is called *polyenergid nucleus*. Now the nuclear membrance breaks and chromosmoes are set free, each set forming a daughter nucleus. Now, the cytoplasm of parent body segregates into small masses, each around a daughter nucleus. A spore case is formed around this cytoplasm. Thus, about 200 spores are formed. *Amoeba* sinks and disintigrates liberating the spores. On return of favourable conditions spore case bursts open by absorbing water, and a small amoeba is liberated from each spore.

3. ***Encystment and multiple fission***. In unfavourable conditions, *Amoeba* becomes rounded and secretes three layered chitinous

cyst around itself. This cyst acts as a protective armour within which *Amoeba* passes an inactive life. It comes out of cyst during favourable conditions. According to some workers the nucleus undergoes repeated mitotic divisions forming about 500 minute daughter nuclei. These nuclei arrange themselves along the periphery of the cyst. A small amount of cytoplasm collects round each nucleus. Forming a daughter *Amoeba* called *amoebula or pseudopodiospore.* When favourable conditions arrive, the cyst breaks off liberating amoebulae, each with fine pseudopodia. They lead an active life and grow into adults in due course of time.

According to modern workers, multiple fission in encysted *Amoeba* is doubtful.

4. ***Conjugation.*** According to some workers, sometimes two amoebae conjugate for some time and then separate to lead their independent lives. Although there is no definite evidence for conjugation.

REGENERATION

Amoeba has a great power of regeneration. If it is cut into small piece, each piece, containing a part of nucleus, rapidly regenerate into a complete *Amoeba.* A piece without nuclear part, does not regenerate and soon dies.

5

ENTAMOEBA HISTOLYTICA

Most amoebae are free-living, but some are endoparasites. They have adapted themselves to live actively in the intestine of many invertebrates and vertebrates. Besides weakening the host body by obtaining nourishment from it, these many cause diseases and, hence, called *pathogenic parasites*. One of such pathogenic amoeabea is *Entamoeba histolytica*. It was discovered by *Lable* (1859). *Losch* (1874) discovered its pathogenic nature. *Koch* (1887) first saw it in the intestinal section. *Kortulis* (1887) in the liver abscess. The name *E. histolytica* was given by *Schaudin* (1903). The structure of this parasite has been studied by *Nollar* (1922) and *Kofoid* (1927). *Elmassion* (1909) and, *Walker* and *Sellards* (1913) studied its precytic stage while *Hartmann* and *Prowazek* (1907) studied it cystic stages. *Dobell* (1909-28) studied its binary fission. *Cleveland* and *Sanders* (1939) studied the excystment. The ultrastructure has been studied by *Miller et al* (1961) and *Feltcher et al* (1962). It causes 'amoebic dysentery or'amoebiasis' that is why it is commonly called 'dysentery amoeba'. *E. histolytica* also occur in other mammals, lower vertebrates and some invertebrates, often without evident damage to these hosts. Laboratory turtles, snakes and frogs are common sources for study. The contents of lower intestine may be examined by diluting with physiological saline solution on slide. Iodine solutions disclose the nuclei in temporary stain, while iron hemotoxylin is preferred for permanent preparation.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Sub-phylum	-	Sarocmastigophora
Superclass	-	Sarcodina
Class	-	Rhizopodea
Sub-class	-	Lobosia
Order	-	Amoebida
Genus	-	*Entamoeba*
Species	-	*histolytica*

Distribution

E. histolytica is world-wide in distribution. It is known to be widely distributed in tropical, subtropical, temperate regions. The incidence is high in India, China, Mexico and parts of S. America. *Craig* (1962) estimated that about 10% of the human population is infected by this parasite.

Habits and habitat

As mentioned *E. histolytica* occurs in man and other mammals like dogs, cats, rats, monkeys, baboon, chimpanzee, gorilla etc. It lives in the upper part of large intestine (colon) of man. It lives in the mucous and submucous layers of colon. It secretes a toxic substance with dissolves and destroys the mucous lining. From here, certain individuals are carried by blood stream to liver, lungs, kidneys, gonads and even the brain. The parasite feeds on the dissolved tissues, bacteria, and blood corpuscles. It causes a serious and often fatal disease known as *amoebic dysentery*. Patients of this disease discharge mucous and blood in their stool.

Morphology

The active motile form of *E. histolytica* is called the *trophozoite* which usually ranges in long diameter from 15 - 25 μ. It resembles *Amoeba* in its structural details. It is bounded by a thin, flexible, transparent semipermeable membrane, the

plasmalemma. The cytoplasm is differentiated into outer ectoplasm and inner endoplasm. The ectoplasm forms a thin, clear, relatively firm outer layer. The endoplasm is granular and more fluid part. A single pseudopodium is formed of ectoplasm only.

In the endoplasm a nucleus and several vacuoles are present. The nucleus is vesicular and rounded. It is bounded by a delicate nuclear membrane, whose inner surface is encrusted with a fine peripheral layer of *chromatin granules*. The *karyosome* or *endosome* is small and centrally placed in the nucleus. It is often surrounded by a clear area or *halo*. The size of nucleus is about 4-6 μ in diameter and it contains six chromosomes.

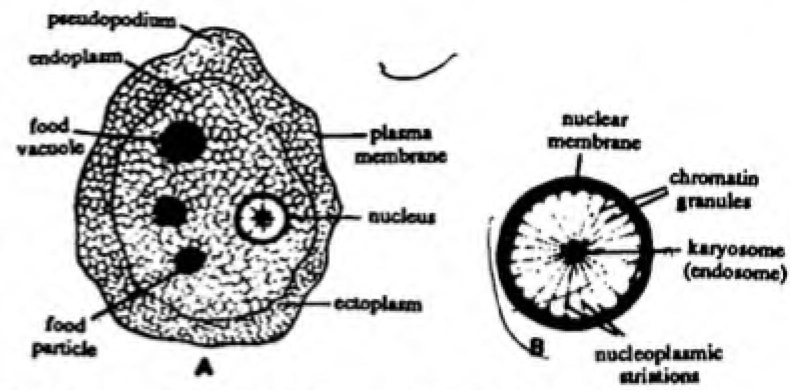

Fig. 5.1 A—Trophozoite of *Entamoeba histolytica*, B—nucleus

In the endoplasm, food vacuoles vary in size and number are present. They enclosing red blood corpuscles, white blood corpuscles and debris of epithetical cells and bacteria. The contractile vacuole is entirely absent.

PHYSIOLOGY

LOCOMOTION

E. histolytica is a monopodial as it gives out a single, large and broad pseudopodium in the direction of movement. The pseudopodium is called *lobopodium*. In the lobopodium, the outer clear ectoplasm remains sharply differentiated from the inner granular endoplasm. The movement is slow and sometimes called *limax type* movement as it resembles the slow crawling of slug (*Limax*).

NUTRITION

The mode of nutrition is *holozoic*. It feeds mainly upon blood corpuscles, fragments of epithetical cells and bacteria. It is believed to secrete *cytolysin*, a protein digesting enzyme that dissolves the epithial mucous membrane and liberates the blood. It than capture blood corpuscles with pseudopodium. It also absorbs substances saprozoically from the surrounding medium.

RESPIRATION

E. histolytica is aerobic when oxygen is available but anaerobic when oxygen is not available. It requires very little oxygen hence *microaerobi*.

EXCRETION

The nitrogenous waste product formed is ammonia which is diffused out in host's tissue.

REPRODUCTION AND LIFE-CYCLE

In *E. histolytica* only asexual reproduction occurs. It occurs in two ways : *binary fission* and *multiple fission*. The binary fission takes place in the active trophozoite in gut of host. Multiple fission starts in the encysted stage in one host and completed in the new host after excystation.

The life cycle includes two phases of development i.e. trophozoite and cyst, with a transitory precystic stage.

Binary fission. The trophosoite multiplies asexually within the wall of intestine of host. The nucleus divides mitotically into two. With this division, the body of the organism is also divided into two by a constriction. They rapidly grow in size, feeding upon the bacteria and the host tissue elements. They again multiply by binary fission. Some of them attack and penetrate fresh

host cells while others, under certain circumstances which are not well known, remain small (7 - 10u in diameter) and retreat into the lumen of the intestine. These small forms are rounded and sluggish and are known as *precystic* or *minuta forms.* The minuta forms do not eat tissue cells and blood corpuscles but feed only on the bacteria. It is the non-motile and non feeding stage thus it is non-pathogenic to man.

Encystment. The precystic forms undergo encystation only in the luman of the intestine. They round up and secrete a thin, flexible, refractile and resistant cyst wall around themselves. The cyst of *E. histolytica* is spherical body measuring 10-15u in diameter. Its cytoplasm is clear and hyaline containing two *chromatoid bodies and many glycogen vacuoles.* According to *Pitelka* (1963), the chromatoid bodies are composed of ribo-nucleoproteins. These bodies disappear as the cyst matures. At this stage the cyst is *uninucleate.* Soon the single nucleus divides mitotically into two and the cyst becomes *binucleate.* Next division results in four nuclei and the cyst now becomes *tetranucleate* or *quadirnucleate.* Now the cysts come out of the body of host with the faeces. The cysts can remain alive for many weeks outside the body of the host till they reach in the new host.

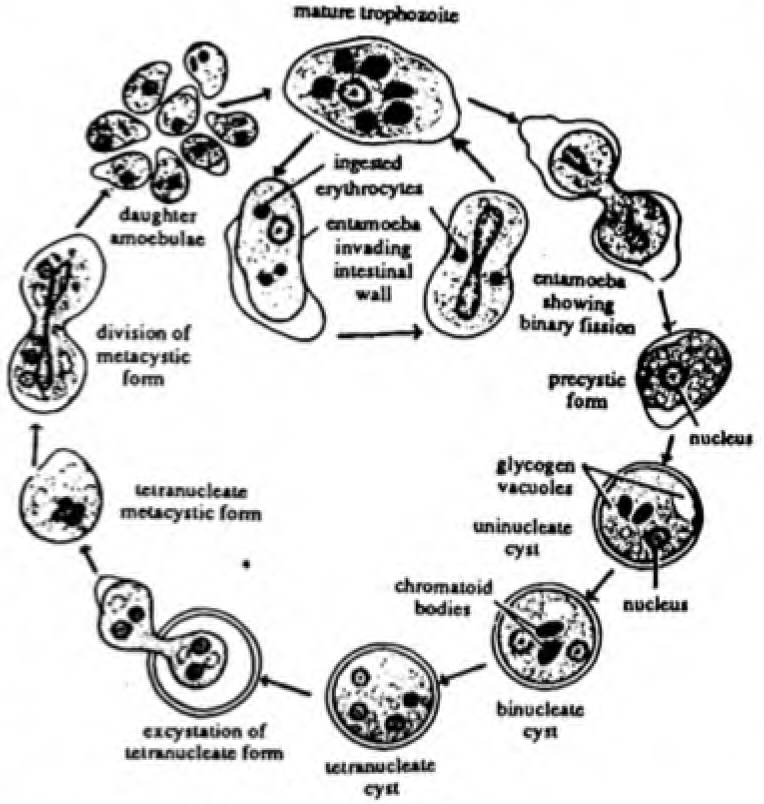

Fig. 5.2 Life-Cycle of *Entamoeba histolytica*

Transfer to new host. The cysts reach the alimenatary canal of new host with contamination of food and water. The food can be contaminated by any of the following water:

(1) By dirty feeding habit.

(2) By coming in contact with contaminated water.

(3) By collection of cysts on food substances by insects like house-fly, cockroach etc.

(4) By eating uncooked vegetables and fruits.

Excystation and ***metacystic forms.*** The excystation of cyst and metacystic development have been observed and studied by *Dobell* (1928) and, *Cleveland* and *Sanders* (1930) in cultures. Excystation is the process of transformation of cysts to the trophozoites. The cysts reach to aliminetary canal of host. There is no effect of gastric juice in stomach on them. On reaching the intestine their cyst wall in dissolved by the action of trypsin and a tetranucleated amoeba (the *metacystic form*) comes out in the lumen of intestine. A metacystic form undergoes a series of nuclear and cytoplasmic division producing eight uninucleate daughter amoebae. The young amoebae being actively motile, make their way into the large intestine, invade the mucous and submucous lining and grow into mature trophozoites.

Pathogenic effects

Although about 10% of human population is infected, yet most of them are carriers and no harm is caused by *Entamoeba histolytica.* According to *Hoarse* (1962), *E. histolytica* is characteristically a great commensal and, only in a few cases symptoms of disease are seen.

1. *Amoebic dysentery.* The trophozoites penetrates the mucosa and submucosa of intestine (colon) and causes its necrosis and form small wounds or abscesses which later become flask-shaped bleeding *ulcers.* The cavity of ulcers is generally filled with mucous, bacteria, amoebae and cell-debris. The abscesses pour their contents into the lumen of intestine. In amoebic

dysentery, the stools are acidic and contain pure blood and mucous in which swarms of amoebae and blood corpuscles, are usually present. The patient is largely discomforted owing to intense gripping pains with the passing of blood and mucous with stools after every few minutes.

2. *Abscesses in liver, lungs and brain.* Sometimes, *E. histolytica* passes into the portal circulation and then to liver where the parasites settle and form abscesses in the liver by attacking the liver tissue. The patient has pain in liver and fever may develop. Lung abscesses may also occur. The trophozoites through blood circulation may also enter spleen, gonads and brain where they also destroy the tissue causing specific abscesses. Abscesses elsewhere are rare. In acute cases, they might prove to be fatal.

Treatment. The permanent cure is sometimes difficult. For prompt relief of acute dysentery the injections of *Emetin* are given. Certain antibiotics such as *Fumgillin, Aureomycin, Erythromycin* and *Terramycin* are more effective for oral treatment. In chronic cases, certain arsenic compound like *Vioform* and *Carbarsone* and iodine compounds such as *Yatran, Didoquin* are effective. For amoebiasis of liver and lungs *Chloquine* is quite effective

Prevention. Following measures are essential in the prevention of the disease:

1. Washing of hand with antiseptic soaps and water before taking food and after toilet.
2. Sanitary disposal of faecal matter.
3. Perfect sanitation and protection of water and vegetable from pollution.
4. Protection of foods and drinks from contamination by house-flies, cockroaches etc.
5. Use of boiled water and properly washing the vegetables and fruits.
6. Avoiding open field and road sides for passing out stools and chemicals treatment of human faeces, if used as fertilizers.

SPECIES OF ENTAMOEBA

Entamoeba coli

It is the most common species to occur in about 50% of the human population world over. It lives in the lumen of colon and does not enter the tissues of the wall. It is a non-pathogenic species as it does not cause any disease to man. It feeds on bacteria, undigested food and other debris but never on the tissue. It is, therefore, called endocommensel.

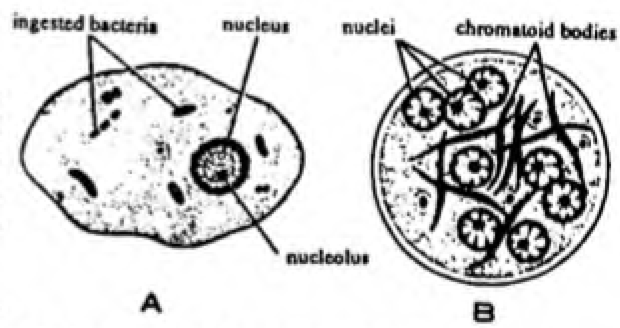

Fig. 5.3 *E. Coli*, A—Trophozoite B—Cyst

Like *E. histolytica* its trophoites measure 15-40u in diameter. The cytoplasm is less distinct in ectoplasm and endoplasm. The nucleus has a comparatively larger nucleus or endosome not placed in the centre. The nucleus measure 5-8u in diameter. Numerous food vacuoles are seen but they contain bacteria, faecal debris etc. The cysts are spherical or often ovoid. Immature cysts contain 1, 2, 4 nuclei while the mature cyst has 8 nuclei. In young cyst besides 4 nuclei one or more glycogen bodies and small number of chromatoid bodies are present. The infection takes place through cysts in stool of infected man passed out and taken by new host by contaminated water or food. Its life-history is now known. According to Hegner, the cysts hatch as 8 nucleated amoebae.

Entamoeba gingivalis

The mouth amoeba, *E. ginglivalis* lives in the mouth usually between the teeth and gums. It is also found in abscesses of gums, tonsils etc. According to *Kofold* 75% people over 40 years of age harbour this amoeba. The trophozoite measures 10-20u in diameter. The cytoplasm in differentiated into an outer clear ectoplasm and a hyaline and vacuolated endoplasm. The nucleus is present in endoplasm measuring 2-4u in diameter. It contains a centrally placed endosome or nucleolus. The trophozoite feeds on bacteria, cellular debries and white blood corpuscles. There are many pseudopodia all are with blunt ends.

In *E. gingivalis* the cyst have not been seen since it is directly transmitted from one human to another by contact during

kissing or in feeding.

It was believed earlier that *E. gingivalis* caused *pyorrhoea*. Fortunately, they are not pathogenic but probably they aggravate the disease of pyorrhoea by destroying the tissues in gums.

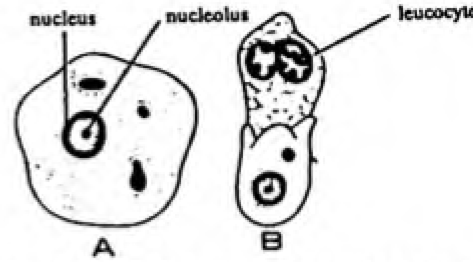

Fig. 5.4 *E. gingivalis*. A—Trophozoite B—Engulfing liecotyte.

Entamoeba hartmanni

E. hartmanni closely resembles the minute or precystic form of *E. histolytica*. It lives in the colon of man, invades the intestinal tissues and cause amoebic dysentery, but is less harmful. The trophozoites measure 9-14u in diameter. The nucleus is more compact. The cystic forms measure less than 10 μ in diameter.

6

ELPHIDIUM OR POLYSTOMELLA

Elphidium is a shelled protozoan belongs to the order-Foraminiferida, class-Rhizopodea. Its shall is perforated by numerous minute pores hence the name Foraminifera (L. *forare*-pores; *feree*-to bear) is given to this order.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Sub-phylum	-	Sarcomastigophora
Super-class	-	Sarcodina
Class	-	Rhizopodea
Sub-class	-	Granuloreticulosia
Order	-	Foramaniferida
Genus	-	*Elphidium*
Species	-	*crispum*

Habits and habitat

Elphidium is a free-living and marine protozoan. It is a bottom dwelling form found at the sea floor to depth of 540-600 meters. It slowly creeps along the sand and sea weeds. It is omnivorous. It shows dimorphism and the life-cycle shows alternation of generations.

Morphology

Body of *Elphidium* is covered with a hard and translucent; biconvex and oval or spherical shell made up of calcium carbonate and silica. The shall is perforated with several chambers (about 45-50). All the chambers are filled with cytoplasm (*Polyhalamous*). The shall is pale-yellow in colour and measures about 1 mm in diameter. The surface of the shall is beautifully chiselled bearing tiny tubercles. The central part of the shall forms the rounded umbo while peripheral part the keel. The chambers of the shall are V-shaped, laid down serially and arranged in a flat spiral in which each whorl of chambers overlaps the previous one i.e. *equitant*. The overlapping portions are called *alar processes*. Due to overlapping of the chambers only the last chamber is visible from outside. The hinder margin of each chamber bears a row of projections, the *retral processes*. The adjacent chambers remain separated from each other by perforated septa through which cytoplasmic continuity is maintained.

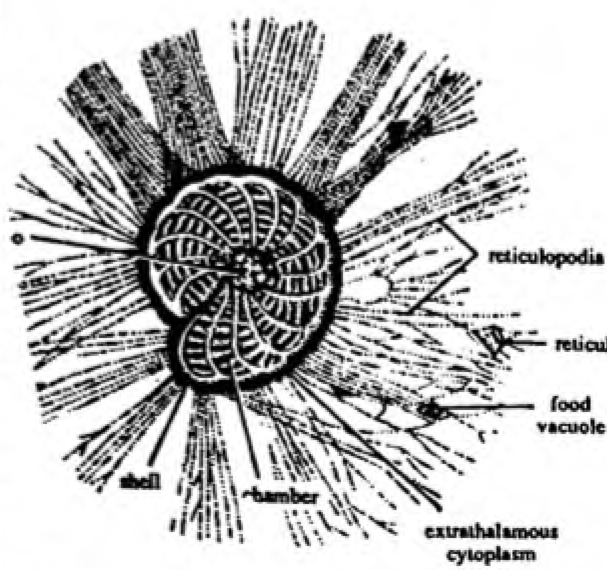

Fig. 6.1 *Elphidium Polytomella*

The first or initial chamber formed by the animal is known as *proloculum*. As the young grows, its cytoplasm

overflows through the aperture of proloculum. The extruded cytoplasm rounds itself off and secretes a new chamber. By the repetition of this process a multichambered shall is formed. Each new chamber is larger than the predecessor.

In *Elphidium* there are two types of shells differisng in relative sizes of the proculum. If the proculum is small and is fromed by the individual developing from zygote, the shall is called *microspheric*. In others the initial chamber or proculum is proportionately larger and they have produced by individuals resulting from schizogony. Such shells are called *megalospheric*. Thus the animals show dimorphism. The differences between two forms given in the table.

Cytoplasm. The shall-chambers are filled with cytoplasm. The cytoplasm is viscous and granular in nature. There is no marked distinction of ectoplasm and endoplasm. The cytoplasm contains single nucleus in megalospheric forms and many nuclei in microspheric forms. The nucleus is vericular in form and contains several nucleoli in its nucleoplasm. The contractile vacuoles are absent. Coloured granules or globules called *xanthosomes*, commonly occur in cytoplasm. These representexcretory matter.

Megalospheric	*Microspheric*
1. Proloculum large but thin walled-diameter 60-100 µ.	1. Proloculum small but thick-walled-diameter about 10 µ.
2. Second chamber horn shaped.	2. Second chamber spherical.
3. Uninucleate.	3. Multinucleate.
4. Gamont-haploid.	4. Schizont-diploid.
5. More common.	5. Less Common.
6. Retral processes present in all the chamber.	6. Retral process found in later chambers only.
7. Rotation of chamber counter clockwise.	7. Rotation of chambers clockwise.

Under electron-microscope ribosomes, endoplasmic reticulum, Golgi-complex, mitochondria are visible.

Pseudopodia. Pseudopodia are temporary protrusion of the cytoplasm by means of which these animals crawl about. They are long, slender, branching and anastomosing. These are known as *reticulopodia* or *myxopodia*. Each reticulopodium consists of an inner fibril-like *axis* and an outer fluid-like *cortex*. They are very active. They are withdrawn and put out very quickly, and freely wave about in water. The reticulopodia are arranged in bundles and help the organisms in locomotion as well as in nutrition.

PHYSIOLOGY

LOCOMOTION

The animal slowly creeps along the sand or sea-weeds at the sea floor. The locomotion is performed by reticulopodia, which help the animal to drag its shell along. The movement is very slow i.e. 4-6 mm. per hour.

NUTRITION

The mode of nutrition is *holozoic*. The animal is omnivorous as it feeds on other protozoans, algae and minute crustancean larvae. The food is traped by pseudopodial net, and is promptly surrounded by cytoplasm. Digestion occurs in food vacuole and is completed before the food reaches the shell.

RESPIRATION AND EXCRETION

The respiration takes place through general body surface by diffusion. Oxygen is taken in and carbon dioxide is eleminated out. The nitrogenous waste products also got rid off by diffusion. The xanthosomes are excretory granules or globules which are passed out by the retracting pseudopodia, as the animal creeps along.

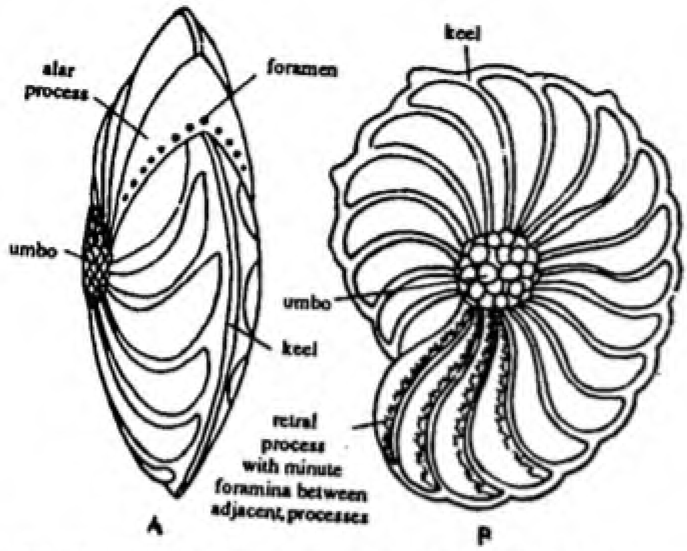

Fig. 6.2 Shell of *Elphidium* A—End on view, B—Lateral view

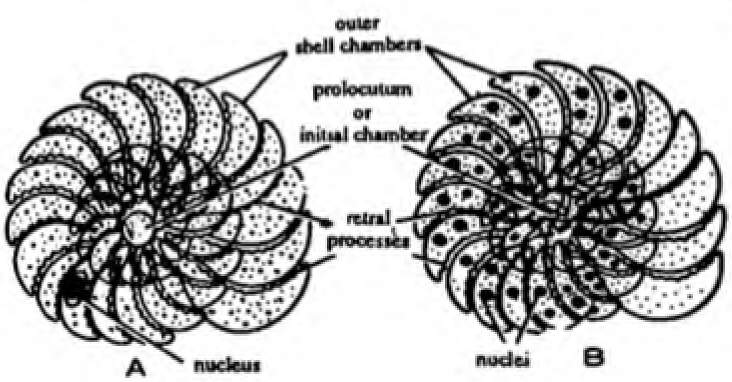

Fig. 6.3 *Elphidium*. A—Macropheric form, B—Micropheric form.

OSMOREGULATION

As the animal is marine so that the osmotic pressure of cytoplasm and its surrounding medium is almost equal. No water enters in the body in excess. Thus there is no necessity of osmoregulation hence the contractile vacuole is absent.

Reproduction and Life-Cycle

The first attempt at the study of life-cycle was made by *Schaudin* (1900). Later *Lister* (1903) added some information on the reproduction in *Polystomella. Myers* (1930-40) made further observations and most of the earlier findings were confirmed by *Le Calvez* (1938, 1950) who provided the first complete account of the life cycle of this genus. *Jepps* (1962) gave a detailed account on the life-cycle. *Grell* (1967) found that gametes are heploid and the amoebulae produced asexually by the microspheric forms are diploid.

Typically there are two generations in the life-cycle of *Elphidium* a sexual one (*gamont*) which alternaties with an asexual one (*schizont*). This alternation of generations is further combined with dimorphism in the adult condition.

1. Asexual phase or microspheric forms.

The microspheric form reproduces asexually which is therefore known as the *agamont* or *schizont.* The microspheric are smallest forms as described by *Schaudin.* It has nine chambers and 28 nuclei. The nuclei are irregularly scattered, although they are absent in terminal chambers. Nuclei multiply by simple division. Nuclei give off irregular strands of darkly staining substances, which are called *chromidia* by some authors.

The first indication of reproduction starts with the great increase in the number of pseudopodia the protoplasm streams out and forms a *halo* around the brown shall. Within a short time, coarse brown granules, the *chromidia* pass out. A large number of new nuclei are recognized from the chromidia. A bit of cytoplasm geathered around each nucleus. These give rise to small amoeboid bodies called *amoebulae* or *pseudopodio spores.* Each amoebula secretes a shall that later becomes proloculum of macrospheric form. New chambers are added as the animal grows in size. Thus a macrospheric form is formed from the microspheric form by multiple fission.

2. Sexual phase or macrospheric forms.

The sexual reproduction occurs in macrospheric forms so that they are called *gamonts.* The nucleus of gamont divides into numerous nuclei and also the cytoplasm. Each nucleus is surrounded by a bit of cytoplasm, which acquires a pair of flagella. This minute biflagellated gamete is called *flagellula* or *zoospore.* The formation of gametes occur within the parental cell. The gametes are released in the surrounding water through the foramina of parent shell, they swim about freely for sometime and then become somewhat elongated. The gametes from different macrospheric forms unite in pairs to form the *zygote.* The zygote loses its flagella. Each zygote secretes a shall around itself and becomes a young microspheric form. The first chamber is small and called proloculum. New chambers are laid down. Nucleus divides several times to form several nuclei. The first division is meiotic so all the nuclei are haploid. With the division of nucleus, the cytoplasm does not divides so a multinucleated condition is found. The microspheric form on becoming full-grown, undergoes asexual reproduction i.e. multiple fission.

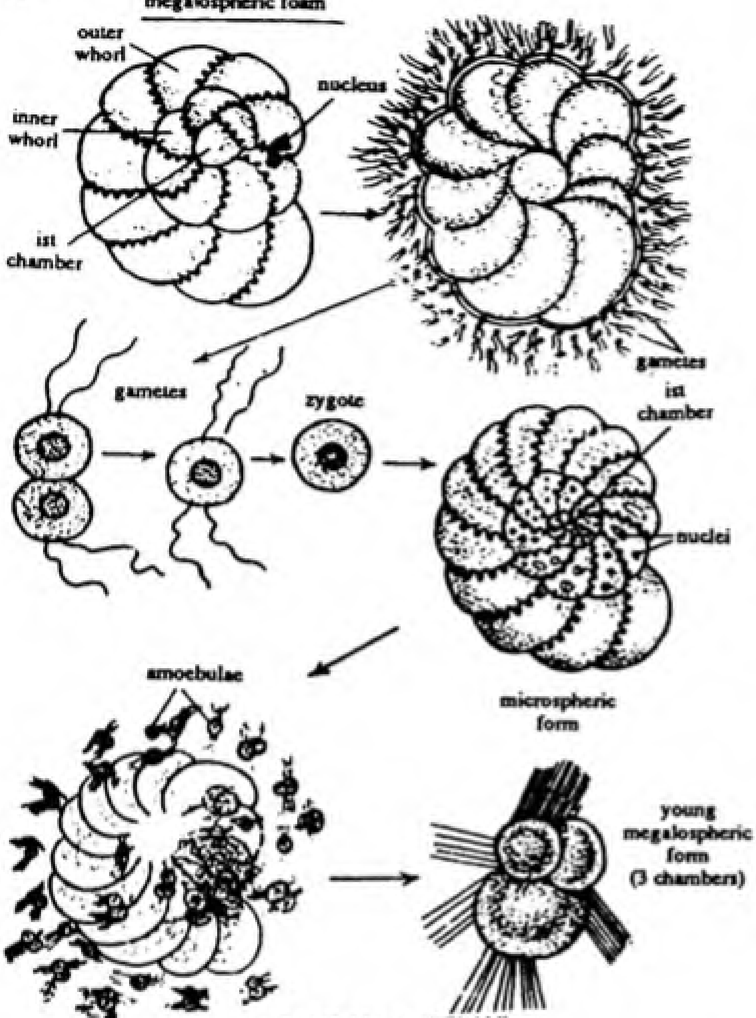

Fig. 7.4 Life history of *Elphidium*

Fig. 6.4 Life history of *Elphidium*

According to *Jepps*, it takes about two years for a complete dimorphic cycle in *Elphidium crispum*. The slow pace of the cycle is related to the amount of growth, the young gamont must undergo before maturity. The gamont develops a test with about 4 or 5 chambers in about eight days. The 6th chamber is complited after about eleven days, the 15th chamber in about one month and usually 40th almost four months. From the above description it is evident that each phase takes a sufficiently long time to mature, and that is why the life-cycle takes a long period.

Alternation of generations.

The life-cycle shows the phenomenon of alternation of generations. The asexual form (the microspheric) gives rise to several amoebulae or pseudopodiospores, which form macrospheric forms (sexual forms). These, in turn, give rise biflagellate isogametes by multiple fission. These gametes fuse to form zygote. The zygote forms macrospheric form. In this manner two generations alternate with each other.

7

RADIOLARIA

Radiolaria are exclusively marine and chiefly plagic. They are found equal well in warm and cold water; littoral or oceanic; surface dweller or inhabiting deep down upto 500 meters. West areas of oceanic floor are covered by the ooze of radiolarians. Many of the radiolarians show bioluminescece. Their zoological history gets back from the *Salurian Period* and they are one of the earliest known animals.

The body is generally spherical and ranges from 50 to several mm., and the colonial forms to several cms. The prevailing symmetry is radial or bilateral although asymmetrical forms are also found.

The cytosome is divided into two regions: an *extra-capsular* and an *intra-capsular* by the central *capsule*. The capsule is a thin, delicate structure of a single or double membrane of pseudo-chitinous or mucoid nature. In shape it is spherical, ovoid, lobate or branched. The capsule may increase in diameter with the growth of animal and it dissolves during fission in simple forms. Perforations either distributed uniformly or concentrated in one or more groups. The perforations permit continuity between the extra-capsular and intra-capsular cytosome. The extra-capsular cystosome is primarily considered with floatation and digestion of food. Three zones are distinguished in it sarcomatrix, calymma and sarcodictyum.

The sarcomatrix or assimilative layer immediately surrounds the central capsule. It contains pigments, excretory substances and undigested food material. In some Tripyleans aggregation of the excretory substances and food material produces greenish or brownish mass surround the aperture of capsule called phoedium. The calymma or the vacuolated layer lies in a wide zone next to sarcomatrix. It is filled with vacuoles containing water, saturated with carbon dioxide which gives buoyancy. When the vacuoles burst the specific gravity of individual increases and it sinks; when the vacuole reappears the specific gravity decreases and the animal rises. In the calymma are usually symbiotic zooxanthellae are present, which are modified dinoflagellate. Zooxanthellae are absent in deep sea individuals. Fat drops, oil spheres and pigments are also present in the calymma. The sarcodictyum is in a thin film on the out side of calymma, from it extends slender filamentous pseudopodia.

The typical pseudopodia are *axopodia* which arise from inside the central capsule and radiate in all directions, some pseudopodia are provided with myoneme, which produce circular group of short, rod like body clustered round each radial spine.

The intra-capsular part is the seat of reproductive activity, it is granular often vacuolated. It contains one or more nuclei, pigments, oil-droplets, fat-globules and crystals. Zooxanthellae are also found in it sometimes.

The skeleton is absent in certain forms as *Thalassicola*. In others the skeleton is present in various stages of development. It is formed of strontium sulphate while other consists of siliceous substances. In Actipylina the skeleton is composed of 20 rods radiating from centre and emerging from body in five circle comparable one equitoreal, two tropical and two circumpolar regions. This arrangements after *Muller* is known as Muller's Law.

The siliceous skeleton may be in the form of rods and spines which usually lies outside the capsule. The rods and spines may be intracapsular or inter-nuclear in some forms like *Acantheria*. The skeleton may be in the form of one or more layers of lattic work, peripheral and concentric with central capsule. In the later case the lattice work may lie in the nucleus, in the intra-capsular cytosome and extra-capsular cytosome.

Radiolarian are not swimmers. Some of them rise and sink in response to changes in the environmental conditions by regeneration or collapse of vacuoles, such a mechanism allows animals living near the surface to sink when the sea is rough or

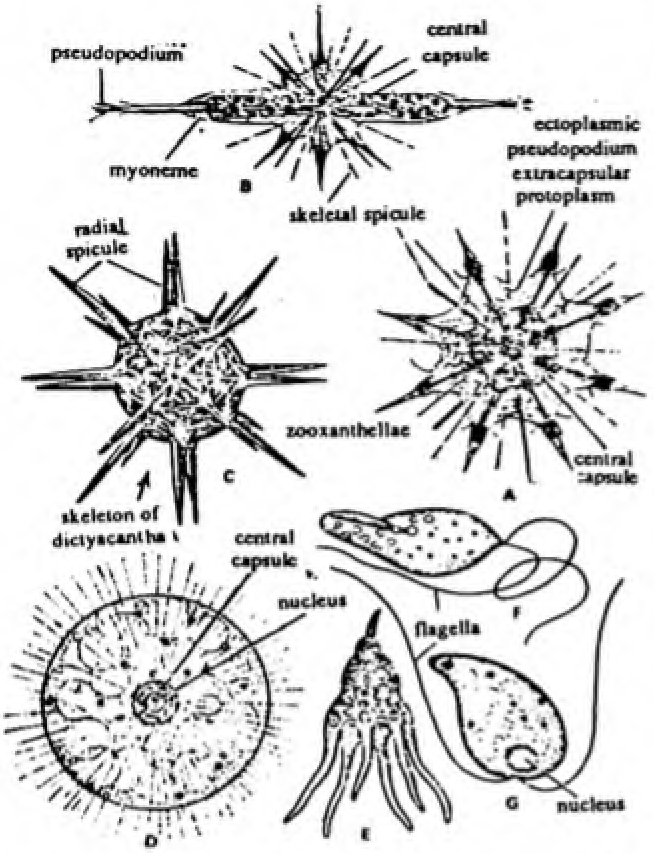

Fig. 7.1 Some Radiolarians. A—*Acanthometra*, B—*Amphilonche*, C—*Dictyocantha*, D—*Thalassicola*

temperature in the upper region of water is unfavourable. The filamentous, cylinder pseudopodia which come out from extracapsular cytosome help in creeping along hard surface.

Radiolarians feed on microplankton like diatoms and various protozoa. The food is captured by pseudopodia and by their contraction is drown in sarcomatrix where it is digisted in food vacuole. Radiolarian, can live without food if kept in sun-light due to zooxanthellae which occur in calymma except in Actipylina where it is found in intra-capsular cytosome. In the absence of organic food the radiolarian lives on the reserve made by zooxanthellae through holophytic nutrition.

Asexual reproduction by *binary fission* occurs in many forms or forms with simple skeleton. In any individual (with a simple skeleton), the central capsule is divided and the skeletal elements are passed to daughter organisms. Fission is also known to occur in helmet-shaped skeleton bearers, in such forms one daughter organism retains the old-shell and the other leaves the parent shall and forms a new skeleton. *Multiple fission* is also known from forms like *Thalassophysa*. The central capsule becomes irregular and the nucleus divides into a number of globules around a number of which cytosome gathered to form small ovoidal masses. Finally the extra-capsular and intra-capsular cytosome breaks up into numerous small multinucleated body. Multiplication by budding also takes place in some forms. The multinucleated individual gives off buds each with a number of nuclei. Buds separate and develop into new individuals.

Sexual reproduction by swarm formation is known in some forms. In *Thalassicola* the central capsule becomes separates from the body and its nucleus divides into vary many nuclei. Around each nucleus cytoplasm gather and each mass develops a flagellum. The capsule now descended to the depth of several hundred metres where it ruptures liberating the swarmers both iso-swarmers (isospores) and anisoswarmers (anisospores). Each isoswarmer is said to contain a crystal and a fat globule. The anisoswarmers contain refractile granules in cytoplasm. Further development is not known. According to *Kudo* the isoswarmers belonging to asexual generation and anisoswarmer to the sexual. *Hyman* considered isoswarmer as isogametes and anisogametes as escaped zooxanthellae. The complete life-history in any case is unkoawn.

8

MONOCYSTIS

One of the largest and best-known acphaline gregarines is *Monocystis*, which almost always can be found in the seminal vesicle of the earthworms, *Pheretima posthuma*, *Lumbricus terrestris*, *L. rubellus* and *L. Castaneus*.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Sub-phylum	-	Sporozora
Class	-	Telosporea
Sub-class	-	Gregarinia
Family	-	Monocystidae
Genus	-	*Monocystis*

Habits and habitat

Monocystis is an inhabitant of a part of reproductive apparatus of the earthworm. Various stages in the life-history are invariably found in the seminal vesicles of earthworm (endoparasites). The common species of *Monocystis* are: *Monocystis lumbrici*, *M. pheretimi* (*Bhatia* and *Chaterjee*), *M. beddardi* (*Ghosh*), *M. lloidi* (*Ghosh*), *M. magna*, *M. agilis* and *M. bengalensis*.

To obtain living parasites, an infected worm can be anesthetized by submerging it in 7% alcohol or 5% chloretone. After such treatment, the anterior third of the animal should be slit open along the mid-dorsal line and the body wall reflected. If small pieces of seminal vesicles, large lobed organs located approximately in segments 9-16, are pinched off with forceps and gently teased in 0.75% NaCl solution, large ciliated - appearing trophozoites (200 by 70 μ and cysts 160 μ in diameter) will readily be found.

MORPHOLOGY

Shape and Size. The *trophozoite* is the adult and feeding stage of the *Mynocystis*. It is an elongated spindle-shaped and flatenned animal. It is about 200μ in length and 70μ in width.

Pellicle. The body of the trophozoite is bounded externally by the thick, smooth and porous pellicle (also called *ectocyte*). It may be modified in various ways i.e., it may be striated or thrown into elevation and furrows or hair-like processes.

In *M. agilis*, at the anterior end and on one side is a small some what pointed rose thorn-like process called *mucron*. It is supposed to help in locomotion.

Cytoplasm. The cytoplasm can be differentiated into outer *ectoplasm* and inner *endoplasm*. The ectoplasm in further differentiated into an outer homogeneous *sarcocyte* and an inner *myocyte*. In the myocyte are found

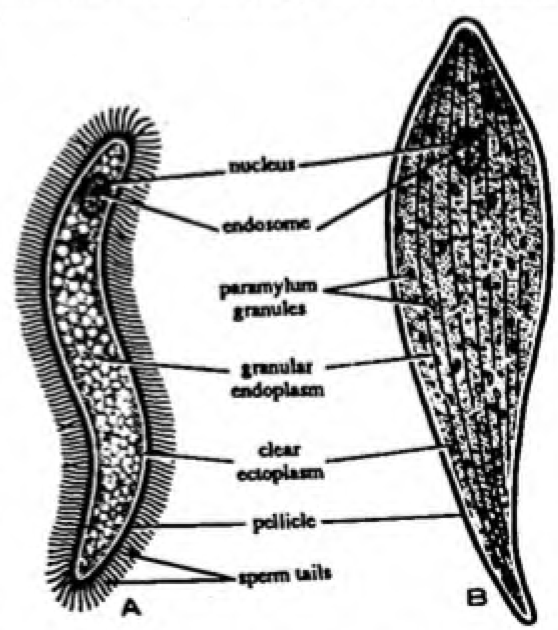

Fig. 8.1 *Monocysts*. A—trophozoite B—Mature trophozoite

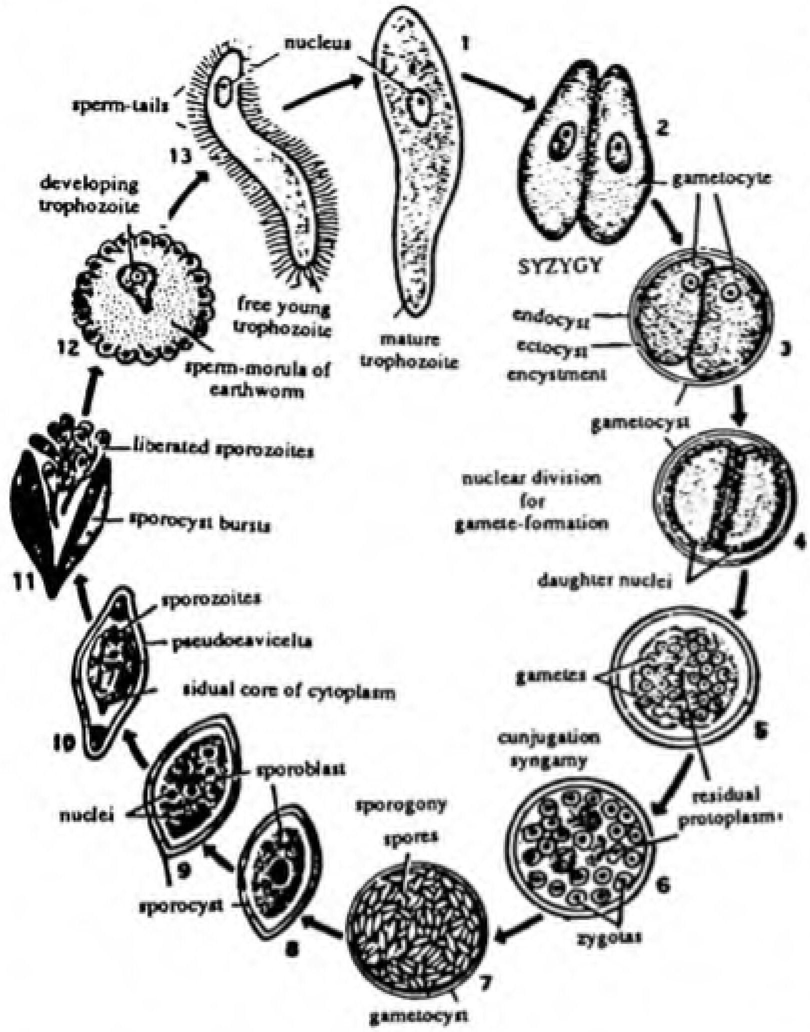

Fig. 8.2 Life cycle of *Monocystis*

longitudinally running tracts of cytoplasm called *myonemes*, especially developed contractile structures. In some species circular myonemes are also present.

The endoplasm contains granules of *paraglycogen* in large number. Besides *volutin* granules and fat globuled are also present.

Nucleus. Within the endoplasm there lies a single vesicular nucleus. It is surrounded by a delicate nuclear membrane and contains a clear liquid in which are suspended denser bodies called *nucleoli* or *karyosomes*. Chromatin is distributed throughout the nucleoplasm.

Under electron microscope the endoplasm is seen to contains other organelles like *Golgi complex, mitochondria* etc. The mitochondria are more in number at the periphery. Due to parasitic mode of life cilia, flagella, contractile vacuole, food vacuoles, cytostome and cytopharynx are absent.

PHYSIOLOGY

Locomotion. Active locomotory organelles are absent in *Monocystis* so that the trophozoite shows only slow wriggling movement brought about be the rhythmical contractions of the myonemes. This type of locomotion is called *gregarine movement* because it occurs in all the members of order Gregarinida. This is similar to the *euglenoid movement* of *Euglena*. In fact, the parasitic mode of life reduces the need of active movement.

Nutrition. Saprozoic type of nutrition is seen in *Monocystis*. It does not ingest food particles like other protozoans (*Amoeba, Paramecium* etc.) Digestive enzymes exude out of its body and render the protoplasm around is assimilable. In this way, the digested food is absorbed through the pellicle. Reserve food material is stored in the form of paraglycogen or paramylon or zoomylon granules. The tails of sperms are attached around it due to which the trophozoite appears as ciliate for sometimes.

Respiration. Respiration is aerobic. The gaseous exchange occurs by diffusion through the pellicle. There is no direct contact with the atmosphere. It gets oxygen from the fluid of seminal vesicle. The carbon dioxide produced in the parasite is diffused out into the surroundings by diffusion. This carbon dioxide finally goes into the blood of host.

Excretion. By the catabolic activities nitrogenous waste products are formed which are also eliminated in the surrounding medium by diffusion. From the medium they are drained away by the blood to be disposed off by the excretory system of host.

Behaviour. Very little is known about the irritability in *Monocystis* as it lives in a remarkably uniform environment so there is no need of any active response by the organism.

REPRODUCTION AND LIFE CYCLE

The life-cycle of *Monocystis* is completed in one host i.e. the earthworm. Thus *Monocystis* is monogenetic. The tropohozoite lives freely for sometimes in the sperm morula (it is a group of developing sperms or spermatozoa) of host. It feeds on the sperm protoplasm and grows in size. Soon the fully adult trophozoite enters the reproductive phase which is divided into three stages:

1. Gametogony or gamontogamy.
2. Syngamy or Conjugation
3. Sporogony.

1. Gametogony.

The gametogony is a method of sexual reproduction which involves pairing of gamonts and formation of gametes.

(a) *Syzygy.* After feeding stage each trophozoite changes into *gametocyte* or *gamont*. Gametocytes come together in pairs. The two then secrete a common resistant and protective cyst wall called *gametocyst* or *gamontocyst* or *association cyst.* The latter word has recently been given by *Marshall* and *Williams* (1972). The cyst wall is bilayered, an outer thick and rigid *ectocyst* or *epicyst* and an inner thin *endocyst*. Fusion or conjugation between two gametocytes does not take place in cyst. This type of pairing of gametocytes is called *syzygy*.

(b) *Gamete Formation.* Within the cyst-wall the gametocytes shrink further and exude some fluid that fills the narrow space between them and endocyst and is called the cystic fluid.

Each gametecyte produce a number of nuclei by the mitotic division of its nucleus. The nuclei thus formed, move to the periphery of gametocytes and each gets surrounded by a small amount of cytoplasm to form gamete. The gametes project from the surface of the gametecyte, giving it the appearance of mulberry. A small amount of cytoplasm is left as *residual cytoplasm* in the gametocyte. This cytoplasm is vacuolated and contains some paraglycogen granules and serves as a medium in which the gametes live. The gametes are *isogametes* in *M. pheretimi* as they are similar in shape and size. They are haploid and each contains 5 chromosomes. Recently it has been suggested, on the basis of new findings of some workers, that sex differentiation occurs between gametes of two gametocytes. These may be in the form of cytoplasmic inclusions or in shape (*anisogametes*). For instance, it has been pointed out that the male gametes have a pointed tail or are flagellated. Flagellated microgametes of *M. marazeki* as founded by *Hahn* can be cited as an example.

The gametes produced in one gametocyte are of the same sex and are equal in number to those formed in its partner.

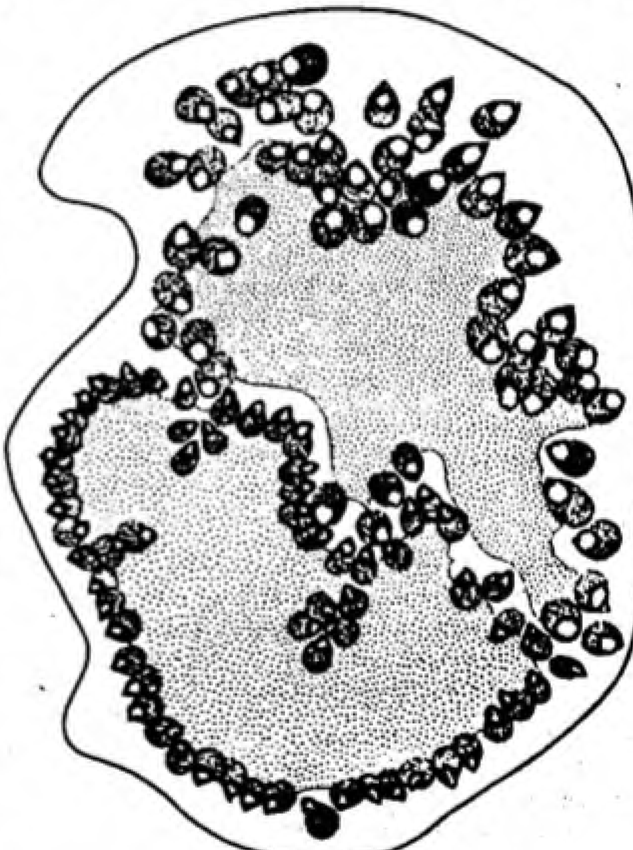

Fig. 8.3 Formation of anisgameter in *Monocystis*

2. Syngamy

It involved the fusion of gametes sooner or later, the middle wall separating the gametocytes break down and their contents intermingled. The gametes now fuse in pairs to produce dipoloid zygotes. It is as a rule that two gametes uniting in a pair come from different gametocyte. Many zygotes are formed within the gametocyst by syngamy.

3. Sporogony

The developing zygote is also called *sporblast.* It is spherical in the beginning but transforms itself into a single-walled boat-shaped body. It secretes around itself single-layered, transparent chitinous wall called *sporcyst.* The sporoblast thus changes into the *spore.* It possesses a mucoid plug at either end. The spore now acquires the characteristic form of a boat resembling a diatom, *Nevicella* and therefore, it was termed by some earlier zoologist as Pseudonevicella, but it is now called zygocyst or spore.

After a brief resting period, the spore undergoes multiple-fission called *sporogony.* In this process, its nucleus is divided three times, the first division is meiotic, resulting in eight nuclei. Each nucleus soon gets surrounded by a bit of cytoplasm. The uninucleated masses of cytoplasm, thus formed, are known as *sporozoites* or *zoites.* Each sporzoite is slender, elongated, sickle-shaped body and, all the sporozoites are arranged like the loculi of an orange around a core of residual cytoplasm. All the sporzoites are hoploid and occur within the gametocyst formed at the time of syzygy.

The spores are liberated into the cavity of seminal vesicle of earthworm by the rupture of the gametocyst. In those species of *Monocystis* where reproduction takes place in coelomic fluid, the spores are found in the posterior region of the body.

The sporozoites can develop further only if the spore containing them are transferred to new host which is no doubt an earthworm.

MODE OF TRANSFERENCE

It is not definitely known as to how the spores of *Monocystis* are transmitted from one host to other. However, their transmission is believed to take place by any of the following methods:

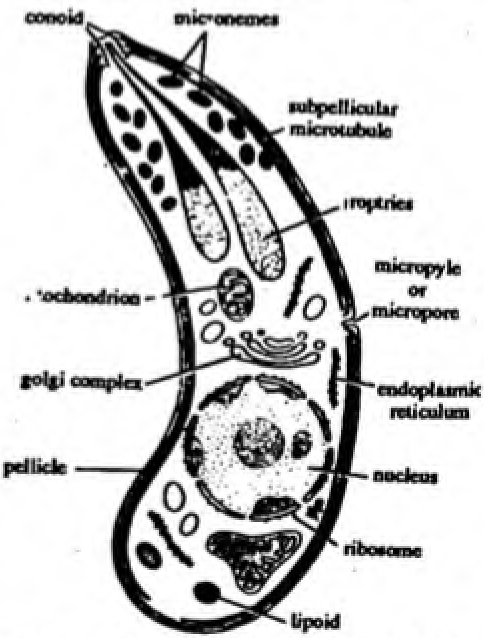

Fig. 8.4 *Monocystis.* A sporozoite seen under electron micro-

1. *By the death of host.* When the host dies and decays, the spores are scattered in the soil. When such soil is eaten by another worm, they reach its alimentary canal.
2. *During copulation.* Some zoologists are of the opinion that the spores are usually transferred from one host to another during copulation, when spermatozoa and seminal fluid of one worm are passed into the spermatheca of another, but spores are never seen in cocoons.
3. *By birds. Pfiffer* found spores in the gut contents of various birds. In such cases sporocysts are passed outside with the excreta of birds into the soil. If such a soil is swallowed up by other worms they start their life cycle again.
4. *Autotomization.* In certain species of *Monocystis* which reproduce in coelomic fluid their spores are found in the posterior segments of the host body, when the posterior body is autotomized and the spores are liberated in the soil. When such soil is swallowed up by other earthworm, the sporozoites start their life-cycle again.

When the spores enter the alimentary canal or new host, the sporocyst breaks or dissolved by the action of digestive enzymes of earthworm. The sporozoites become free into the lumen of alimentary canal. The sporozoite are spindle-shaped organisms. Each contains a nucleus, one or two mitochondria, Golgi complex. The pellicle forms the shape of sporozote. At the anterior most region there is a pair of secretory organelles or *roptries.* These structures secrete a secretion which helps in penetration through the tissues. At the anterior end besides the roptries *conoid* and *micronemes* of unknown function are present.

Being actively motile the sporozoites pass out through the alimentary canal into the coelom and than migrate into the seminal vesicles. On reaching the seminal vesicles of a new host each sporozoite penetrates into a new sperm morula, becomes a trophozoite, and the life cycle begins again.

Effect of Parasitism

1. *On the Earthworm. Monocystis* seems to cause no appreciable harm to the host. No doubt it feeds on the spermatozoa, but this does not affect the fertility of the host because the earthworm produced a large number of sperms. The worm is able to combat the parasites by forming a resistant envelope around the trophozites and by killing the cysts through phagocytosis.
2. *On the Parasite.* Due to planty of food and almost no competition inside the seminal vesicles of earthworm, the trophozoite of *Monocystis* undergoes an extreme simplification of structure. The locomotory organelles, food vacuoles, contractile vacuoles, oral apparatus etc. are absent.

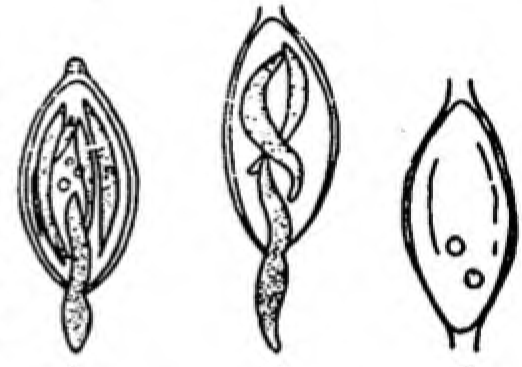

Fig. 8.5 Liberation of *sporozoites* A and B hatching of sporozoites in intestine of host and C = empty sporocyst

Conclusions from the life-history of *Monocystis*.

From the structure and life-history following conclusions can be derived:

1. The organism is *monogenetic* i.e. the life-cycle is completed in one host.
2. Reproduction is only by conjugation or syngamy. The gametes produced are either isogamous or anisogamous, but the pairing gametes are derived from different gametocytes hence the gametes are *exogamous*.
3. No alternation of generation as there is no alternation of asexual and sexual phases.
4. Neither the trophozoite nor the sporozoite is free-living.
5. As the sporozoites are subjected to pass through adverse condition outside the body of host, hence, are protected by sporocyst.
6. Due to parasitic mode of life, the locomotory organelles, food vacuoles, contractile vacuoles, etc. are absent.
7. Respiration and excretion by simple diffusion.

9

PLASMODIUM (MALARIAL PARASITE)

Plasmodium is a member of class-Telosporea of phylum Protozoa. It is a parasite and cause malaria fever in man and other animals. Malaria (Gr. *mal* bad; *aria* - air) meaning bad air, was so named as it was previously thought that damp night-air of marshes and swamps caused this disease. Malarial parasite was first discovered by *Charls Laveran* (1880), who was, a doctor in the French Army stationed Algiers. He observed *Plasmodium* in the blood of a malaria - patient. *King* (1883) reported that *Plasmodium* were transmitted by mosquitoes. The observation of *Laveran* were confirmed by *Golgi* (1885) and *Callie* (1885). *Patric Manson* suggested that the malarial parasite enters the blood of man after the bite of mosquito. He placed his suggestion before *Sir Ronald Ross* in 1894. In 1895 *Ross* undertook this problem and after continuous labour of two year in 1897 proved that *Plasmodium* are sucked up by female *Anopheles* mosquito and are later on injected into the human blood. *Grassi* described the life cycle of *Plasmodium* in the stomach of *Anopheles* female. *Granham, Bird* and *Baker* (1960) studied ultra structure of the sporozoites occur in birds. *Granham et. al.* (1961, 1963) studied ultrastructure of sporozoites occur in human.

There are about 60 species of *Plasmodium* which cause malaria in man and other animals.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Sub-phylum	-	Sporozoa
Class	-	Telosporea
Sub-class	-	Coccidia
Genus	-	*Plasmodium*

Four species of *Plasmodium* are known to cause different types of malaria in man. These are *Plasmodium vivix, P. malariae, P. falciparum,* and *P. berghei found in rats P. rats and P. gallinaceum* in chickens.

HABITS AND HABITAT

Plasmodium is an intracellular parasite in red blood corpuscles of man. It is most widely distributed in both temperate and tropical regions. It has two hosts: (a) man or any other vertebrate (reptiles, birds and mammals) which are called *primary hosts* or *definitive hosts* and (b) female *Anopheles* mosquitoes or other blood sucking insects which are *secondary hosts* or intermediate hosts. The life history is completed in the above two hosts: *asexual* in man and *sexual* in female *Anopheles.* The common species of *Anopheles* which cause malaria in India are *A. stephensi, A. maculatus, A. fluvialitis* and *A. culcifancis.*

MORPHOLOGY

Structure. The adult parasite is called as *Trophozoite* that lives in red blood corpuscles of man. It is amoeboid, uninucleated with granules and vacuoles in the cytoplasm. The granules are chiefly of *haemozoin* pigments. The trophozoite feeds upon the substance of R.B.C.

Its ultrastructure has been studied by *Granham* (1966) and *Rudzinska* (1969). It possesses a double membrane, the *plasmalemma* which is closely applied to the cytoplasm. The endoplasmic reticulum is in the form of small vesicles, which are both smooth and rough type. Free ribosomes are present in cytoplasm. Mitochondria are few and posses double membrane, the

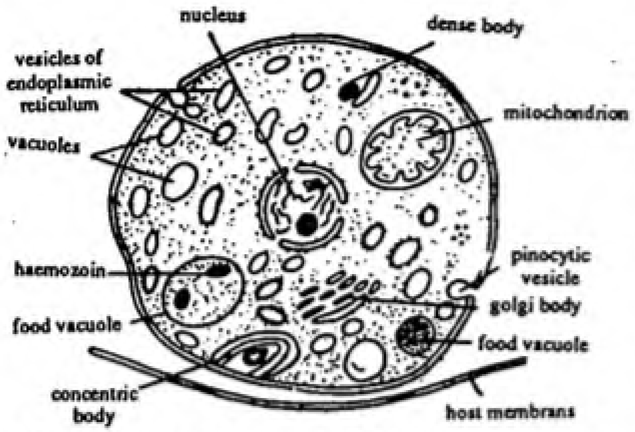

Fig. 9.1 *Plasmodium* Ultrastructure of Trophozoite

cristae are peripheral while the central region is structureless. Golgi complex is composed of small vesicles arranged in rows. Double-membrane concentric structures in the trophozoites are believed to work as mitochondria. One or two double membrane vacuoles with structureless matrix are present their function is unknown. The nuclear membrane is double to which are attached ribosomes. An endosomes or nucleolus lies eccentrally in the nucleus. Pinocytic vacuoles are common in cytoplasm.

The trophozoite feeds upon the haemoglobin of R.B.C. Digestion is intracellular. The residual product called haemozoin is scattered throughout the cytoplasm. Liquid food is taken by the process called pinocytosis.

LIFE-CYCLE

The life-cycle of *Plasmodium vivex* is *digenetic* as its life-cycle is completed in two hosts-man and the *Anopheles* mosquito. The life-cycle is not started by the trophozoite but by the *sporozoite* (*Marshall* and *Williams*, 1972). The life-cycle may be subdivided into three phases; a phase of growth and asexual multiplication occuring in man and called *schizogony*, sexual phase or *gamogony* which starts in man and completed in mosquito; and an asexual multiplication phase in mosquito called *sporogony*. Previously it was thought that there were only two phases in the life-cycle.

1. Schizogony

When a female *Anopheles* bites a man to suck the blood, then along with saliva it inject the *sporzoites* of *Plasmodium* into the human blood. Each sporozoite measures 6-15μ in length. These are sickle-shaped single-nucleated sporozoite. *Granham et. al.* (1961, 1963) studied sporozoite under electron microscope. According to them the pellicle is outer membrane made up of three layers and an intermediate zone is distinguishable. It is continuous over the whole organism except anteriorly and at the base of the micropyle. At the anterior end lies a cup-shaped structure with three concentric rings. The contractile fibres are present.

In about half an hour after their incubation, the sporozoites leave the blood and they enter the parenchymal calls of liver where they undergo at least two schizogonic cycles.

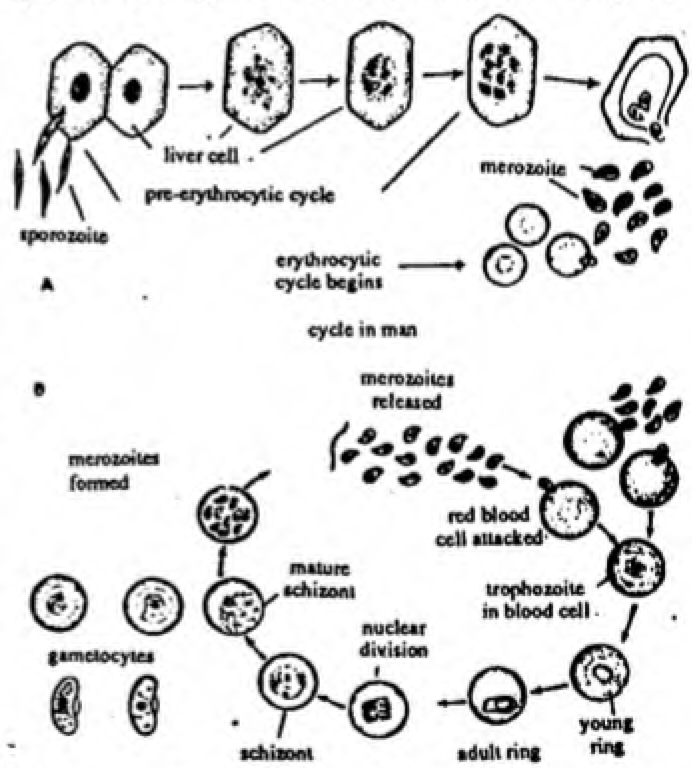

Fig. 9.2 A—*Exoerythrocytic* cycle in man B—*Erythrocytic* cycle in man

(a) *Pre-erythrocytic cycle.* Sporozoites rapidly grow in size in liver cells by absorbing nourishment. Here they become spherical and are called *schizonts.* They measure 10-40μ in diameter. The nucleus of sporozoite divides into several nuclei. Now the schizont is called *cryptozoite.* Each nucleus is surrounded by a bit of cytoplasm and called *cryptomerzoite.* Their number is about 80-1000. Cryptomerozoite measures 1.2 in diameter. Due to pressure of cryptomerozoites the body of cryptozoite, as well as, the host liver cell bursts liberating the cryptomerozoites into liver sinusoids.

(b) *Exo-erythroeytic cycle.* The cryptomerozoites of pre-erythrocytic cycle, which again invade fresh liver cells, grow into adult-like forms, called *metacryptozoites* or *phanerozoites.* The metacryptozoites are of two types *micrometacryptozoites* and *macrometacryptozoites.* Each micrometacryptozoite undergoes schizogony to produce about 100-1000 minute

micrometacryptomerozoites. These are liberated in blood stream by the rupture of metacryptozoite. Each macro-metacryptozoite also undergoes schizogony so as to produce 64 *macrometacryptomerozoites*, which are liberated in blood and invade fresh liver cells to continue exoerythrocytic cycle. Thus, the liver cells provide a sort of reservoir for relapse of fever. On the exoerythrocytic cycle there is no effect of various drugs as the parasite is intracellular. Hosts are acquire immunity to the infection. The period of biting of mosquito in man and entry of merozoites in blood is called *pre-patent period*. It takes about 10 days.

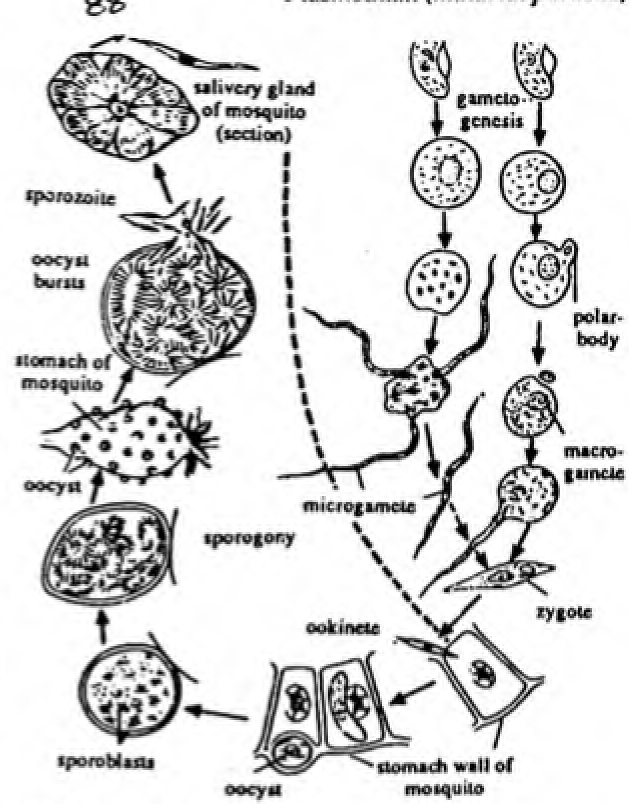

Fig. 9.3 Sexual cycle in *mosquito*.

Erythrocytic Schizogony. After their release from liver cells the merozoites penetrate into the red blood corpuscles. Their elongated shape is lost. Inside the corpusle, the parasite assumes a rounded form and start growing at the expense of R.B.C. During the growth period it is called the *trophozoite*. Soon a vacuole is formed in the cytoplasm of the trophozoite which pushes the nucleus to one side. This gives the trophozoite an appearance of a signet-ring hence this stage is called *signet-ring stage*. This trophozoite is 1/3 to 1/2 the size of R.B.C. With the further growth, the vacuole disappears and the trophozoite now assumes amoeboid shape. Now it is called *amoeboid stage*. The haemoglobin of the R.B.C. is not digested and gets decomposed into a yellowish-brown or black pigment, the *melanin* or *haemozoin* which lies scattered in the cytoplasm. In about 36 hours the trophozoite becomes mature. It again becomes rounded and is ready for multiple fission and now called as *schizont*. Yellowish or orange-coloured dots appear in the cytoplasm of the infected erythrocyte, these dots are called *Schuffner's dots*.

The nucleus of schizont divides repeatedly, forming 12-24 nuclei. Each daughter - nucleus is surrounded by a bit of cytoplasm to form *merozoite* or *Schizozoite*. They are shorter and thicker then sporozoites and oval in shape. A small portion of the cytoplasm of schizont is not utilized in the formation of merozoites. This residual cytoplasm contains melanin and waste products or toxins. The merozoites arrange themselves round the cytoplasm like the petals of a flower hence this stage is called *rosette stage*. The infected corpuscles by this (after 48 hours from the entrance) time becomes very weak and easily burst liberating merozoites in the blood stream. These invade fresh corpuscles to repeat the erythrocytic cycle. The *ghost*, left behind after merozoite's escape, are destroyed in the spleen. Some merozoites are always destroyed by W.B.C.

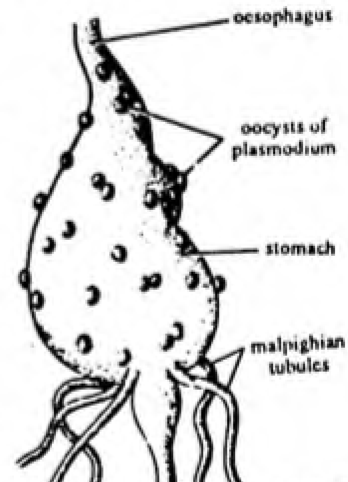

Fig. 9.4 Stomach of infected female *Anopheles* with oocyst, of *plasmodium*.

With the rupturing of the R.B.Cs., the patient suffers an attack of malaria. The fever has been attributed to the release of toxins from the merozoites. The interval between inoculation of sporozoites into human blood and first attack of fever is called *incubation period*.

2. Gametogony

It starts in man and completed in mosquito. After a number of repeated erythrocytic schizogony, the mesozoites do not proceed ahead with erythrocytic cycle, but after entering the R.B.Cs., increase in size to become rounded *gametocytes* or *gamonts*. Growth of merozoites into gametocytes is rather slow and characterised by absence of signet-ring stage. The gametocytes have a large, central nucleus and denser cytoplasm due to the presence of numerous haemozoin granules. The gametocytes are of two type, *male* or *microgametocytes* and *female* or *macrogametocytes*. The microgametocyte is small and contains a large central

diffused nucleus. The female gametocyte is larger and contains a small and eccentric nucleus. The cytoplasm contains fewer granules. The gametocytes do not divide, but remain as intracellular parasites within their host R.B.Cs., until they either die or are ingested by the victor, in which they continue their development.

Sexual cycle in Mosquito

When the female *Anopheles* mosquito sucks the blood of malarial patient the gametocytes and also the merozoites reach in its stomach along with the blood. Except gametocytes all other are digested. The gametocytes now come out of R.B.Cs. The microgametocytes become active. The nucleus of each divides into 6 to 8 haploid nuclei move to the surface of microgametocyte. The cytoplasm of microgametocyte segregates around these nuclei. Suddenly, each cytoplasmic mass, together with its nucleus, shoots out from the surface in the form of whip-like *microgamete* or *sperm* each measuring 20-25μ length. The process is called exflagellation.

Macrogametocyte undergoes invisible changes till some of its nuclear material and cytoplasm is expelled out in the form of a *polar body*, or in other words it undergoes a maturation division, the resulting large body is a *female* or *macrogamete* or *ovum*.

Fertilization. Microgametes make active lashing movements and approach macrogametes. One of the microgametes reaches the protoplasmic projection called cone of reception of macrogamete. The nuclei of microgamete and macrogamete fuse, resulting in the formation of zygote or *synkaryon* with a diploid nucleus.

The zygote remains inactive for sometimes but later on it becomes elongated or worm-like or vermiform and motile. It performs gliding movement and is known as *ookinete*. It measures 15-22μ in length and 3μ in width.

The ultrastructure of ookinete is given by *Granham et. al.* (1962). It is enclosed in two layered envelope made up of an outer folded and inner smooth layer. The micropyle is absent. The nucleus is granular with an endosome. At anterior end, inner layer is more dense and is splitted so as to appear like a mouth. It moves into the stomach of mosquito, there it pass on into the epithelium and finally reaches in-between the epithelial and subepithelial tissues. Ookinete becomes enclosed in a cyst called *oocyst*. The oocyst is thin, membranous and elastic. It is partly secreted by the ookinet and partly derived from the mid-gut of the host. It grows in size absorbing nourishment from the insect through previous cyst-wall. The oocysts look as rounded projections on the surface of the stomach. A single infected mosquito may contain 500-5000 such oocysts.

3. Sporogony

The cytoplasm of the oocyst develops a number of vacuoles and its nucleus divides repeatedly to form a very large number of daughter nuclei. The first division is always a meiotic division and subsequent divisions are mitotic (*Bano*, 1959). Thus the nuclei produced are haploid. Each daughter nucleus gets surrounded by a mass of cytoplasm. The resulting cells are called the *sporozoites*. Each oocyst contains about 10,000 sporozoites. Each sporozoite has tapering ends and a broad middle part containing a single nucleus. The full-grown sporozoite break off from the residual cytoplasm of the oocyst. When the oocysts rupture, the sporzoites are liberated in the haemocoel of mosquito. Being motile, the sporozoites move to different organs in the body of mosquito but the majority migrate into the salivary glands and wait for their transmission into the blood of man while the mosquito bites. It has been estimated that the salivary glands of a single infected mosquito may contain about 200,000 sporozoites. One bite of such a mosquito may inject upto 1000 sporozoites in man. Cycles in mosquito lasts for 2-4 months.

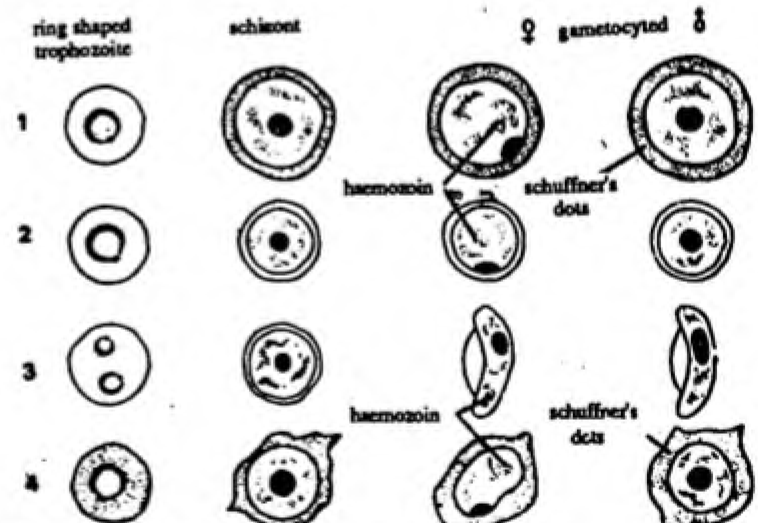

Fig. 9.5 Species of *Plasmodium* 1—*P. vivex*, 2—*P. malaria*, 3—, *P. falciparum*, 4—*P. ovale*

KINDS OF HUMAN MALARIA

The malaria fever is of three type. The names of these three are according to the period of recurrence of the fever. Moreover, these three types of fever are caused by different species of *Plasmodium*. The fever are:

1. ***Tertian Fever.*** The fever comes on every third day. It is cause by the presence of *P. vivex*, *P. falciparum* and *P. ovale*. It is of two types.
   (i) *Benign tertian.* It is due the presence of *P. vivex* and *P. ovale*. The temperature of patient may rise up 106°F but also comes down soon. It is not a fatal one.
   (ii) *Malignant tertian.* It is due to the presence of *P. falciparum*. The temperature of the patient does not rise much but other complication take place. The red blood corpuscles, in which the parasites are living, aggregate to block the blood capillaries due to which the proper blood supply is stopped to different organs of the patient. It is fatal.
2. ***Quartan Fever.*** The fever comes on every 4th day in this. It is caused by the presence of *P. malariae*. It is not fatal.
3. ***Mixed Fever.*** A patient can suffer both mild tertian and malignant tertian at the same time. Similarly, tertian and quartan can combine to cause mixed fever. In such conditions, the fever comes on every day.

A comperative account of four species of
human infecting *Plasmodium*

	Character	*P. vivex*	*P. malariae*	*P. ovale*	*P. falciparum*
1.	Distribution	Widely distributed in tropical and sub-tropical countries	World wide, in tropical and sub-tropical regions	Tropical Africa	Very Common in tropical countries
2.	Incubation period	10-14 days	18-28 days	10-14 days	9-12 days
3.	Duration of erythrocytic schizogony	48 hours	72 hours	48 hours	48 hours
4.	Duration of exoerythrocytic cytic cycle	8 days	14-15 days	9 days	5 days
5.	No. of cryptozoites per schizont	10,000	15,000	15,000	30,000
6.	No of merozoites per schizont	12-24	6-12	6-12	8-20
7.	Arrangement of merozoites	In two circles	Rosette-shaped	In one circle	Irregular
8.	Shape of trophozoites	Amoeboid	Band-shaped and compact	Large and compact	Small and compact
9.	Infected R.B.C.	Large, swollen, distorted and pale with Schuffner's dots	Not enlarged, no dots	Slightly enlarged dots irregular, dot numerous	Normal sized, no dots
10.	Haemozoin granules	Light brown, masses	Dark-brown to abundant	Dark-brown, in compact	Dark-brown in compact mass
11.	Schizont in R.B.C.	Occupies more than 2/3 of R.B.C.	Almost entire R.B.C.	About 3/4	Less than 2/3
12.	Gametocytes	Rounded or oval	Circular or ovoid	Rounded	Crescentric
13.	Microgametocyte	7-8 μ wide with numerous haemozoin granules; 4-8 male gametes produced	Large nucleus with numerous and scattered haemozoin, 4-8 male gametes produced	Similar to *P. vivex*	Haemozoin golden brown 2-5 gametes are produced
14.	Macrogametocyte	8-10 m wide, large, few haemozoin	Small nucleus, coarse haemozoin	Same as in *P. vivex*	Dark, coarse haemozoin around the nucleus
15.	Duration of sexual cycle	10 days	25 days	16 days	10-12 days

Symptoms

Prodromal Symptom. In a typical malarial infection, mild symptoms appear early, even during incubation period. These include loss of appetite, nausea and sometimes sleeplessness. Tongue may be thickly coated. Headache, muscular pain and aches in joints develop.

Paroxym. It is the actual attack of malaria which occurs after a few initial erythrocytic cycles. The period of paroxym varies from person to person. It includes:

(a) *Rigor stage.* That patient feels a terrible chill and shivering, rapid pulse and breathing.

(b) *Febrile stage.* Shivering subside in about one hour or so and the body temperature rises to 104°F to 105°F.

(c) *Defervescent stage.* After a few hours, profuse sweating starts, temperature of body steadily drops and the patient feels healthy again.

Control of Malaria.

The measures for control of malaria may be divided into three categories.

I. Destruction of the victor or *Anopheles* mosquitoes.

II. Presentation of infection or *Prophylaxis.*

III. Treatment of disease

I. Destruction of the victor

This is being done in following ways:

(1) Destruction of adult mosquitoes.

(i) By spraying D.D.T.; Flit, melathion or any other insecticide in the houses.

(ii) By fumigating pyrethrum, cresol and other compounds of neptha.

(iii) By killing them after traping them in small boxes made of wire gauze and internally lined by black paper.

(iv) By sterlization of mosquitoes in now being achieved in Japan.

(2) *Destruction of larvae and pupae.* The larvae and pupae live in stagnant water. They can be destroyed.

(i) Dirty water should not be allowed to collect at a place.

(ii) In large bodies of water, kerosine oil, paraffin oil etc. should be spread on the surface.

(iii) By introducing insectivorous predators like ducks, fishes (*Gambusia*) and some plants like *Utricularia.*

II Prevention of infection.

(1) The houses should be made mosquitoes free by building human dwellings on high grounds, keeping houses clean ventilated, and covering doors and windows with meshes and screens.

(2) Sleep in mosquito-net.

(3) Mosquito repellent cream should be applied on the exposed parts of the body before going to sleep.

(4) Anti-malarial drugs should be taken regularly to escape the attack of malaria. These drugs are *quinine, paludrine, deraprin* etc.

III Treatment of Malaria.

Qunine, Atabrine, Camoquin, Chlorquine, Paludrine, Resochin, Pentaquine etc. are the medicician to check to malarial fever. *Daraprim* is the most effective drug. Its single dose of 25 mg. causes the schizonts of *P. vivex* and *P. falciparum* to disappear.

10

EIMERIA

Eimeria is a parasite like *Monocystis. Elmeria schubergi* was discovered by German biologist *Fritz Schaudin* in 1900. He called this parasite as *Cocidium schubergi* and worked out its life cycle.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Sub-phylum	-	Sporozoa
Class	-	Telosporea
Sub-class	-	Coccidia
Family	-	Eimeriidae
Genus	-	*Eimeria*
Species	-	*schubergi.*

Habits and habitat

E. schubergi is an cytozoic or intracellular parasite in the epithelial cells of alimentary canal of centipede, *Lithobius forficatus.* For some time it lives in the lumen of alimentary canal as a *coelozoic parasite.* The greater part of the life-cycle of *E. schubergi* is spent in the host and a part in open.

Morphology

A full grown trophozoite is somewhat spherical body with a single nucleus. The nucleus contains a single endosome in its centre. Due to parasite mode of life, the locomoty organelles, mouth, gullet, contractile vacuoles etc. are absent.

Physiology

Locomotion. Although the locomotory structures are absent but it moves about in the alimentary canal, progressing by gliding movements, alternating these by flexions, bending itself like a bow and straightening out again. Inside the epithelial cell, it lives a quiescent life.

Nutrition. It feeds in a saprozoic manner, absorbing food in dissolved form. It also subsists on the contents of the cell of the host in which it is living. When in the open, it subsists on the reserved food materials, which is derived from the host's cells before leaving them.

Respiration and excretion. Both take place by the diffusion.

LIFE CYCLE

E. schubergi is a digenetic and shows an alternation of generation. The life-cycle may be divided into three phases:

1. Schizogony
2. Gamogony
3. Sporogony

1. Schizogony

The parasite enters the host in the form of oocyst. When swallowed the oocyst hatches in the small intetine of host (probably under the influence of mechanical pressure and enzymes). From each oocyst eight motile *sporozoites* are released. Each sporozoite has a tiny sickle-shaped body tapering at both the ends. A nucleus is present in the broad middle part. They measure 15-20 by 4-6μ. The spotozoite move apart by gliding, bending and constriction movements till they reach the surface of the epithelium of gut. Each sporozoite penetrates into an epithelial cell of the alimentary canal of the host. When it enters in a cell, it becomes retracted to an ovoid mass of cytoplasm, which measures 16μ in lingth and about 8μ in width. This stage is known as *trophozoite*. The ovoid body of trophozoite grows quickly, increase in length and thickness. In about 24 hours, the trophozoite becomes full-grown, then it is termed as *schizont*. It is spherical and has a diameter of about 20μ. There is no reserve material in cytoplasm. There is a large vesicular nucleus with a karyosome. Multiple fission occurs in schizont. In this process, its nucleus devided repeatedly to form 30-40 nuclei, which migrate to the periphery, each passes into a finger-like projection arising from the surface of schizont. The small uninucleated parasite thus formed is called *merozoite* or *schizozoite*. The portion of cytoplasm in the centre of schizont is termed residual cytoplasm. Merozoites remain attached in a radiating manner. Each merozoite measures about 15u in breadth. By this time the host cell becomes very week because its contents have been used up by the parasite. The merozoites break from residual cytoplasm of schizont and finally escape into the lumen of gut by the rupture of host cell. The merozoites resemble sporozoites in form, structure and movement but differ from them in being slightly shorter and in having a karysome in the nucleus. The cytoplasm is differentiated into an anterior vacuolated and a posterior denser area instead of being more uniformly vacuolated. The merozoites penetrate fresh epithelial cells, grow into trophozoite and repeat schizogony. The process of multiplication is repeated several times till many parasites are formed. Parasites face difficulty in procuring proper nourishment. Asexual multiplication remains in progress for about 5 days during which 4-5 generations of merozoites are produced and then sexual phase is starts.

2. Gamogony

For sexual phase, some of the merozoites instead of growing into schozonts develop into two distinct forms known as *male* or *microgametocytes* and *female* or *macrogametocytes*. The male gametocytes are spherical and have clear cytoplasm while the female gametocytes are bean-shaped and have their cytoplasm crowded with reserve food material. Male gametocyte divide to form numerous narrow, biflagellate *microgametes*. Each measures 6-7μ. in length and about 1u in width. The flagella are as long or longer than the body. It consists almost entirely of nucleus, the cytoplasm being represented by the flagella alone. One of flagellum is free, while the other runs the hind end.

The macrogametes produces a single *macrogamete*. Its karyosome break up into a number of small pieces, which pass from the nucleus into the cytoplasm and finally leave the gametocyte altogether. With this the macrogametocyte changes into female gamete or macrogamete or *hologamete*. Now the hologamete frees itself from the epithelial cell and develops a small projection, the *cone of reception*, on one side. The nucleus also moves towards the cone. This makes the macrogamete ready for fertilization.

The male gamete, also liberated in the lumen of gut. Some male gametes are attracted towards the female gamete only after maturation division. One of the microgamete enters the female gamete through the cone of reception. The flagella of microgamete are shed and left out. Soon a prominent spindle appears in the macrogamete and the chromatin of its nucleus are spread over the spindle. The chromatin of microgamete lies for some time at one pole of the spindle, but later on also spreads over the spindle and gets thoroughly mixed up with that of the macrogamete. This is called syngamy or karyogamy, converting gametes into a zygote.

The zygote soon gets enclosed in a thin, transparent membrane. Later on this membrane becomes thick and tough to serve as a protective envelope, the *oocyst*. As a rule the oocyst does not develop further in the lumen of gut and the young oocyst passes to the exterior with the faeces. The oocyst are very resistant and can survive highly adverse conditions.

3. Sporogony

The size of oocyst does not increase. Its nucleus divides twice to produce four nuclei. The first division is meiosis. The cytoplasm divides into four portions or *sporoblasts*. A portion of cytoplasm of zygote is left unused as the residual body, here termed the *cystal residium*. Each sporoblast secetes, round itself, a cyst called *sporocyst*. Within each sporocyst, the sporoblast continue its development. It divides and produces two tiny parasites, the *sporozoites* and a large residual body is left which is unused part of food material. The unused cytoplasm is termed *sporal residium*. Thus each oocyst contains four sporoblasts and

each sporoblast, two sporozoites. The oocyst here called *tetrasporous* and the sporocyst as *dizoic*. The development of oocyst upto the formation of sporzoites takes two to three days and it is in open i.e. out side the body of host. At this stage it is ready for ingestion by new host. When it reaches the new host the valve of sporozoite is ruptured and eight sporozoites are liberated in gut. The sporozoites attack the epithelial cells of gut and start schizogony.

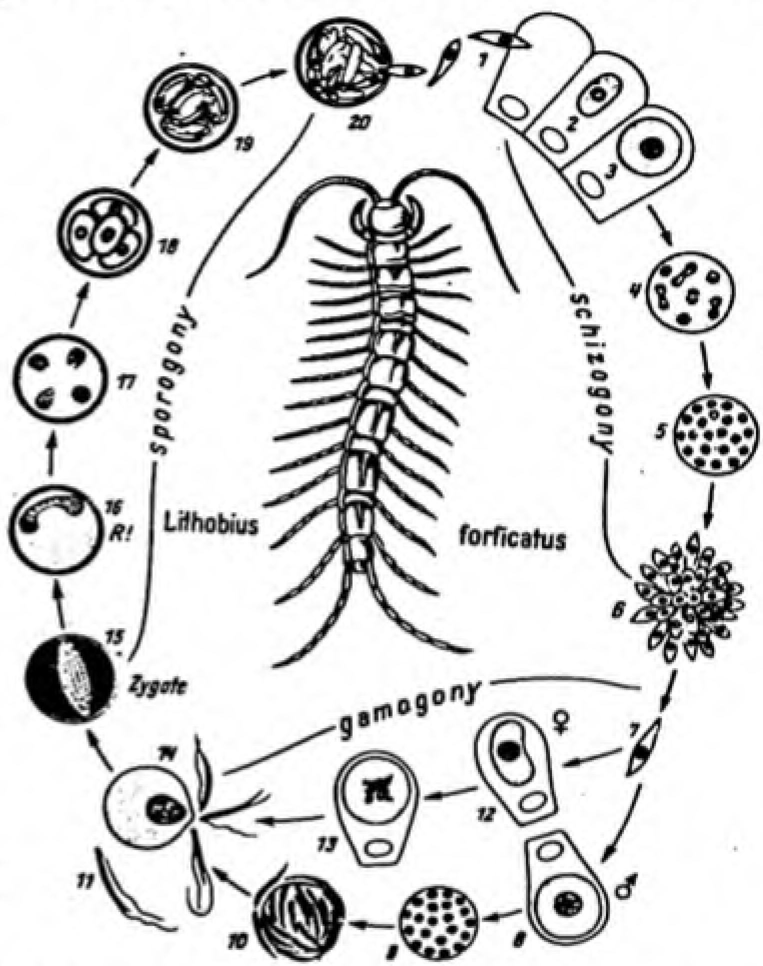

Fig. 10.1 Life-cycle of *Eimeria schubergi*

Alternation of Generation

The life cycle of *Eimeria* shows alternation of generations. The schizogony and sporogony constitute the asexual generations as in these reproduction occurs by asexual method of multiple fission. The gamogony represent the sexual generation as it involves the formation of male and female gametes and their fusion results in the formation of zygote. Schizogony is repeated several times but it does not continue indefinitely. The sexual generation is followed by asexual generation. The phenomenon in which the sexual and asexual generation are followed by each other regularly is called alternation of generations.

Effects on host

Eimeria causes an extensive damage to the epithelial cells of the intestine and attached cells. However, these damage is *ephemeral* as the epithelial calls are soon regenerated. Some species of *Eimeria* are very harmful to the host and they render an economic loss to the man. These species are *E. tenella* of chick, *E. stiedae, E. magna, E. sciurorum, E. perforans* of rabbits; *E. debliecki* of pigs and *E. bovis* of cattles.

A disease is called *coccidiosis*, in which the large scale destruction of intestinal epithelium is accompanied by haemorrhage. The symptoms of coccidiosis are loss of appetite, anaemia, diarrhoea, bloody stool, weakness and sometimes fever. It often proves fatal.

11

PARAMECIUM

Paramecium is the widely studied type of the class-Ciliata. The members of Class Ciliata are much more developed then the other protozoans. Inspite of their being acellular, special organelles are found in them for ingestion, excretion etc. Thus division of labour is clearly seen in ciliates.

SYSTEMATIC POSITION

Phylum	-	Protozoa
Subphylum	-	Ciliophora
Class	-	Ciliata
Sub-class	-	Holotrichia
Order	-	Hymenostomatida
Family	-	Paramecidae
Genus	-	*Paramecium*

HABITS AND HABITAT

Paramecium is cosmopolitan in distribution. It is found in fresh water lakes, ponds, puddles, sewage pipes and rice fields. It is abundent in stagnant water containing decaying organic matter. It is omnivorus in diet and reproduces in a variety of ways, which are asexual and sexual both.

There are 10 species of *Paramecium*. They differ in shape, size, number of micronuclei etc. The common species are *Paramecium caudatum P. aurelia, P. bursaria* and *P. multimicronucleatum*

CULTURE

For general laboratory purpose, *P. caudatum* will grow satisfactorily on a boiled-hay infusion medium to which wheat or rice grains have been added. It has also been maintained on several complex sterile media and simplest of which the yeast juice. Paramecia are easily grown in chalky medium (Nacl-80mg., $NaHCO_3$ - 4mg, $CaCl_2$ - 4 mg, KCl - 4 mg and CaH_4 (PO_4) H_2O 1.6 mg. all are dissolved in one litre of distilled water). Add 6 - 8 drops of skimmed milk weekly. The jar is kept away from direct light.

Other less uniform but very satisfactor method of growing paramecia include a monofloral suspension of bacterium, *Pseudomonas ovalis*, and a suspension of pure, living yeart.

MOROPHOLOGY

External Feature

Shape and Size. The first description of *Paramecium* was given by *Christian Huygens* (1678). The term *Paramecium* was coined for the first time by *John Hill* (1752) from the Greek word *paramekos* meaning oblong. *Paramecium*, in general appearance appears like the sole of the slipper, hence it is popularly known as "*Slipper - animalcule.*" One species was named *P. caudatum* (Joblot) because of its resemblance to an imprint of human foot.

They vary in size. The largest species *P. caudatum* measures 180-300 μ in length; *P. aurclia* is 170-250 μ, and *P. trichium* measures only 62 μ in length.

Colour. Some species are somewhat translucent and colourless, others are vary from light gray, white to pale yellow. *P. burseria* is green because of the presence of *Zoochlorellae* in the endoplasm.

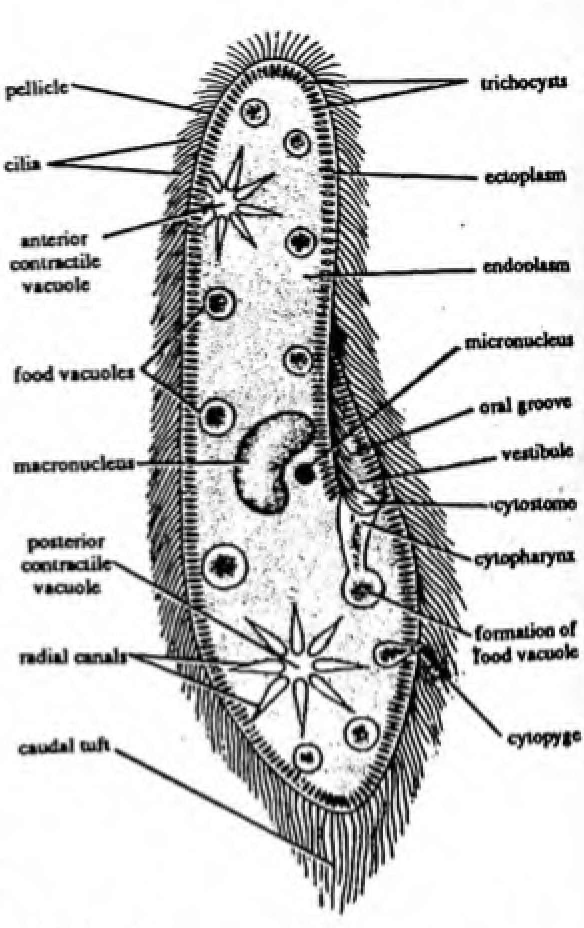

Fig. 11.1 *Paramecium caudatum*

Structure. The shape of the body is definet because the body of ciliates is typically covered by a complex, living *pellicle*, usually containing a number of different organelles. Under light microscope the pellicle appears homogenous. Under electron-microscope the pellicle has inflated kidney - shaped *alveoli*. The inflated condition and the shape of alveoli produce a polygonal space about the one or two cilia that arise between them. Alternating the alveoli are bottle shaped organelles, the *trichocysts*, which form a second, deeper compact layer of the pellicular system. *Ehert* and *Powers* (1959) showed that pellicle is made up of three membranes, the outer most being the plasma membrane which covers the whole organism including the cilia. Beneath it, in most place, there are two further membranes, the *outer* and *inner membranes* the outer and inner membranes bounding a flattened alveolus would thus form a middle and inner membrane of the pellicle.

The alveoli contribute to the stability of the pellicle and perhaps limit the permeability of the cell-surface (*Pitelka*, 1970).

Ciliature. The entire surface of *Paramecium* is covered by innurmerable fine structures called *cilia*. They are arranged on the body in parallel rows. On the body proper the cilia are of the moderate and fairly uniform length, but at the extreme posterior end they become longer forming the *caudal tuft*. The cilia found in oral apparatus show a wide range of variation in length. Each cilium measure 10-16u in length and 0.1-.2u in width. The number of cilia varies from 350 (*P. trichrium*) to 18000. In *P. caudatum* their number is 10,000 - 14,000. According to *Gelei* (1925) the number of cilia is 18000 in *P. nephridiatum*.

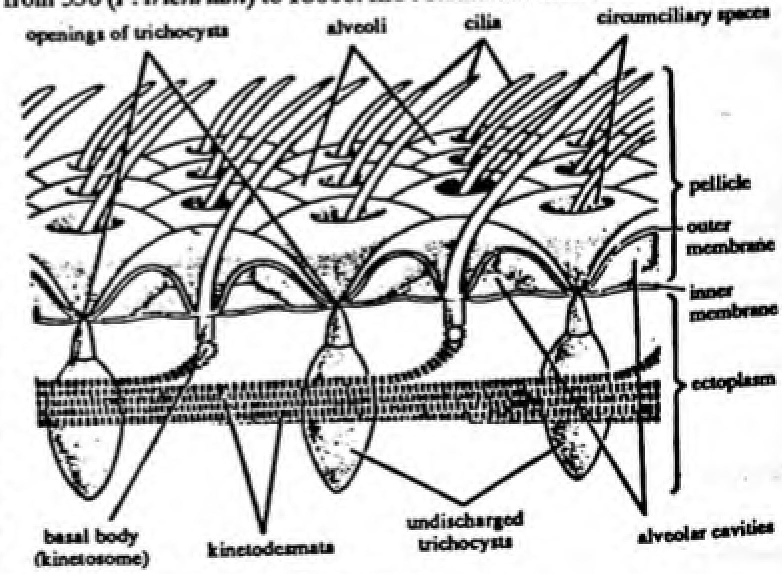

Fig. 11.2 Pellicular system in *Paramecium*

As already stated that the cilium comes out from the centre of alveoi of the pellicle. In *P. aurelia* and *P. bursaria* two cilia arise from each area.

Cilia have the same structure as flagella. It consists of an axial filament, the *axoneme*, embedded in an elastic protoplasmic *sheath*, which is continuous with the outer membrane of the pellicle. The axial filament is itself formed of eleven fibrils that extends its full length. Nine of these fibrils are double and occur in a ring called *peripheral fibres*. Each is composed of two adhering subfibres, one of which is provided with a pair of arms all disposed in same direction. The remaining two are *central fibres* which are independent surrounded by a thin membraneous *central sheath*. Nine radially directed fibres are disposed between the peripheal fibres and the inner

sheath like spokes of a wheel. The peripheral fibres continued below into the basal body or *Kinetosome*.

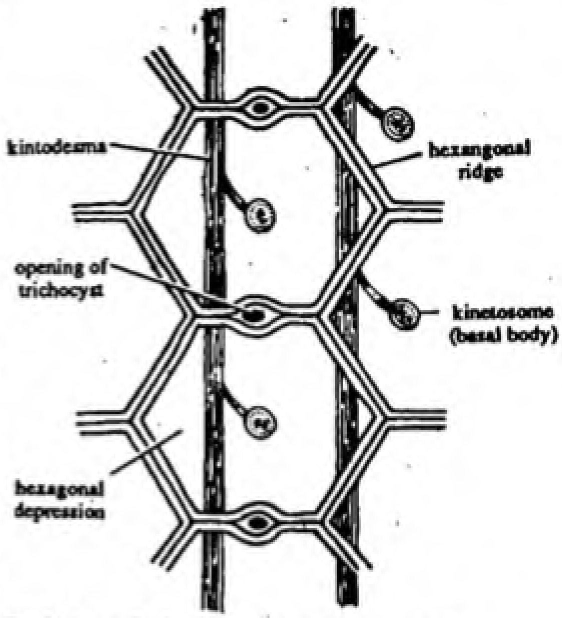

Fig. 11.3 Surface view of a past of *Paramecium*

Internal Features

Cytoplasm. The cytoplasm is differentiated into an outer ectoplasm and inner endoplasm.

1. *Ectoplasm.* It is clear and dense part of the cytoplasm which forms its outer layer below the pellicle. In the ectoplasm occurs following three important structures.

(i) *Trichocysts.* Trichocysts are peculiar, rod-like or oval organelles characteristic of many ciliates. They are oriented at right angles to the body surface being located at the centre of the anterior and posterior walls of the pellicular polygons. The trichocysts are small in size only 4μ in length. They lie a little (1 - 2μ) below the pellicle to which each is attached by a very delicate fibre.

An undischarged trichocyst is a *sac* containing a *swelling substance* (the quelkorper) and closed by a *cap*. Just within the cap is a conical *spike* resting on a *basis*. The discharged trichocyst consists of a long, striated, thread-like shaft surmounted by a barb. The shaft is not evident in the undischarged trichocysts and is probably polymerized in the process of discharge. The trichocysts are discharged on mechanical, chemical or electric stimuli. They are discharged very rapidly (within several milliseconds).

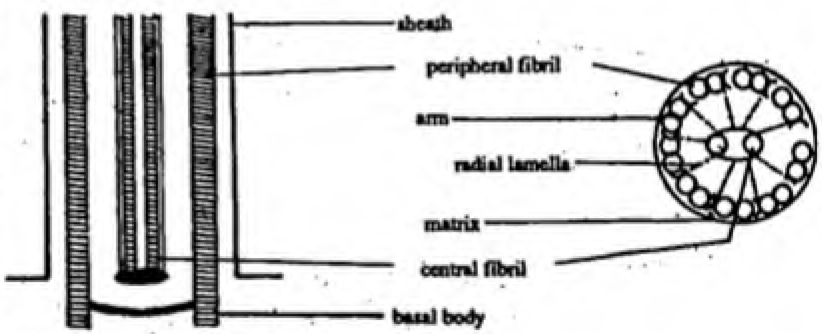

Fig. 11.4 L.S. and T.S. of *Cilium*

The trichocysts are *non-toxic* type in *Paramecium* thus they are not defensive organelle. Probably they may be used in anchoring the animal when feeding.

Area in the neighbouring of the nucleus is believed to the centre of origin of trichocysts. Recently, it has been established that trichocysts are produced by the kinetosomes. A kinetosome first ejects a *trichocysts granule* or *tricystosome* which forms a budding that develops into a trichocyst.

(ii) *Infra-ciliary system.* As mentioned earlier, each cilium arises from a basal body or kinetosome, located in the alveolar layer. The kinetosomes that form a particular longitudinal row are connected by means of fine, striated fibrils, called *kinetodesma*. The kinetosomes plus the fibrils of that row make up a *kinety*. The longitudinal bundle of fibrils run to the right side of the row of kinetosomes, and each kinetosome gives rise to one kinetodesoms (fibril), which joins the longitudinal bundle and extends anteriorly. A single kinetodesmos is tapered and extends for varying distance, as a part of bundle. At the kinetosome, the kinetodesmos is connected to certain of the kinetosome triplets.

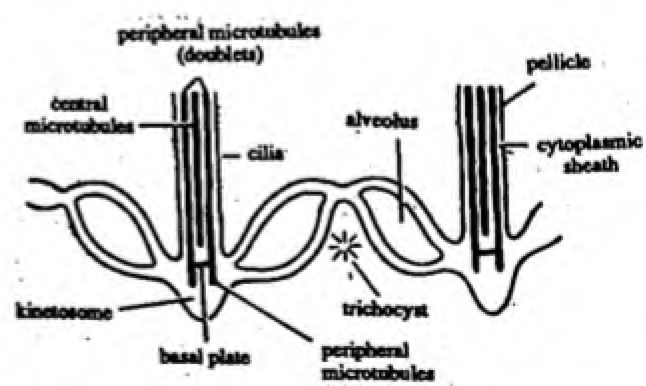

Fig. 11.5 V.S. through the surface of *Paramecium* to show position of cilia, kinetosome and trichocyst

A kinety system is characteristic of all ciliates although there are variations in details of the pattern. The kineties with their cilia constitute the neurolocomotor organelle. The kineties control and coordinate the beating of cilia.

(iii) *The fibrillar system or Neuromotor apparatus.* The fibrillar system is visible with the help of nuclear stains. According to *Lund* (1933) on the left dorsal wall of the cytopharynx at about the level of posterior margin of the cytostome is a very small, bilobed mass called *neuromotorium.* From neuromotorium, fibrils radiate into the endoplasm. Of these four or more usually pass almost to the dorsal body wall but rest are shorter and not definite in position. Their function is uncertain and apparently function as part of the cilium anchorage system.

But the electron microscopic studies reveal only the presence of the alveoli, kinetosomes and kinetodesmata and there is no evidence regarding the existence of this system.

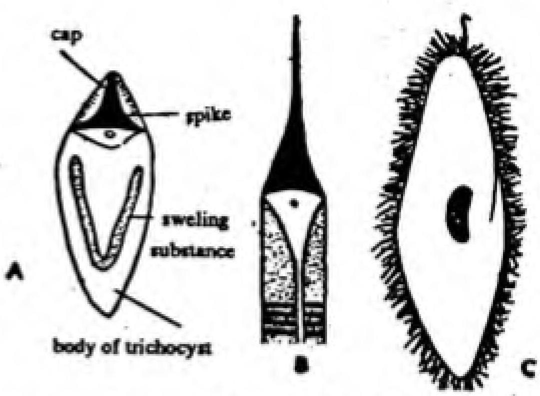

Fig. 11.6 *Trichocyst.* A—entire, B—tip of discharged Trichocyst, C—Trichocysts discharged after staining with ink.

2. Endoplasm

The endoplasm of *Paramecium* is semi-fluid and less granular. It contains following structures.

(i) *Nucleus. Paramecium* is *hereokaryotic* having two types of nuclei. The smaller one or the *micronucleus* is lodged in a depression at one side of the larger nucleus called *meganucleus* or *macronucleus.* The meganucleus is bean or kidney shaped body lying approximately in the centre. It is a compact structure, containing fine threads and tightly packed discrete chromatic granules of variable size. The meganucleus controls the vegetative activities of the animal.

The micronuclei vary in number in different species. These are smaller structure and may be compact (*P. caudatum*) or vesicular (*P. aurelia*). *P. cadatum* and *P. bursaria* each has one micronucleus. *P. aurelia* has two and *P. multimicronucleatum* has 3-9 micronuclei. The micronuclei are concerned with reproduction.

(ii) *Contractile Vacuoles.* In *Paramecium* there are two contractile vacuoles occupying somewhat fixed positions in the endoplasm. One vacuole is located at both the posterior and anterior end of the body. (In *P. multimicronucleatum* there are 2-7 contractile vacuoles). The anterior vacuole is sometimes called the *nuclear vacuole* being near the nucleus and the posterior one is called the *peristomial vacuole* being in vicinity of peristome. Each contractile vacuole is surrounded by 5-12 *radiating canals.* Each radiating canal consists of (a) a tabular terminal part (b) an ampulla and (c) an injector canal. The injector canal opens into the vacuole. Electron microcopy reveals that the outer or terminal part is surrounded by a network of fine coiled *nephridial tubules* (*Elliot* and *Bak,* 1964). The nephridial tubules collect water from the endoplasm and pass into the terminal part. This fluid is collected in the ampulla which becomes bulb-like when distended, but when the fluid passed out it is of same diameter as the terminal part. When the ampulla is fully distended (diastole) it collapses (systole) and the fluid is passed through the injector canal to form the contractile vacuole. Thus it is

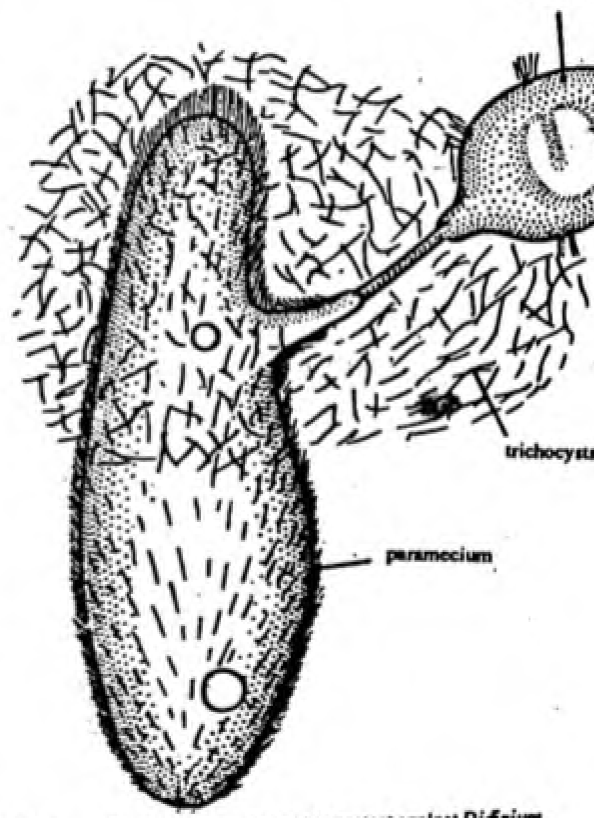

Fig. 11.7 Trychocysts ...ows out to protect against *Didinium.*

apparent that the systole of ampulla becomes the diastole of the vacuole. In *P. trichium* the contractile vacuole is without radial canals. The contractile vacuole opens outside through *discharge canal.* Bundles of fibres surround the ampullae and the main vacuoles, and concerned in the production or control of the pressure required to control the vacuole.

The contractile vacuoles pulsate at different rates depending on their position. The posterior vacuole pulsates faster than the anterior vacuole because of large amount of water being delivered into the posterior region by the cytopharynx.

(iii) **Food vacuoles.** These are roughly spherical, non contractile bodies varying in size and number lying in the endoplasm. They contain ingested food materials, mainly bacteria and a small amount of water. *Volkovsky* (1934) proposed the name *gastrioles* for these vacuoles.

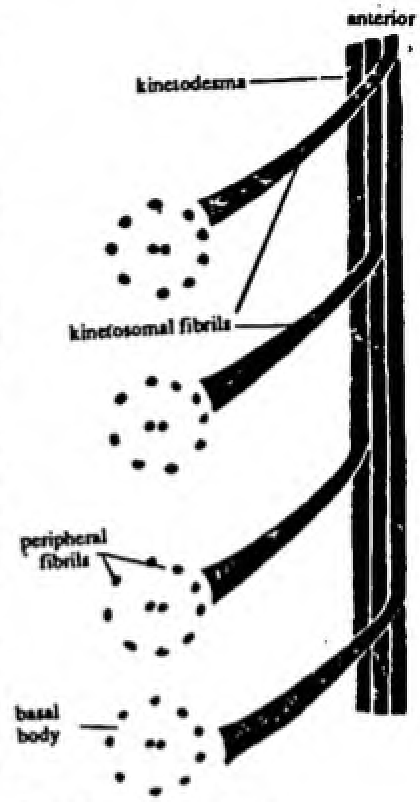

Fig. 11.8 A *Ciliary kinety*

Oral groove and associated structures. The oral groove is located on the ventral surface extending back-wards into a funnel shaped depression known as *vestibule* consisting of invaginated body pellicle. The vestibule leads into buccal cavity which directly leads into the *cytostome* or *mouth* which is fixed oral opening. The cytostome directly opens into the wide *cytopharynx* or *pharynx* which extends toward the centre of body. The cytopharynx forms a food vacuole at the posterior end.

Large and hard cilia are present in these structures. These are specialized cilia and form four organelles which help in food ingestion.

(a) *Endoral membrane.* It is formed by the fusion of one row of cilia. It runs transversely along the right wall and partly encirciles the opening of vestibule into cytostome.

(b) *Dorsal peniculus.* This is formed by four rows of densly arranged cilia which are placed in a spiral manner on the left side of buccal cavity. They end behind the cytostome.

(c) *Ventral peniculus.* It is also formed by four rows of cilia. It extends backwards to a distance on the left side of buccal cavity and ends near the cytostome.

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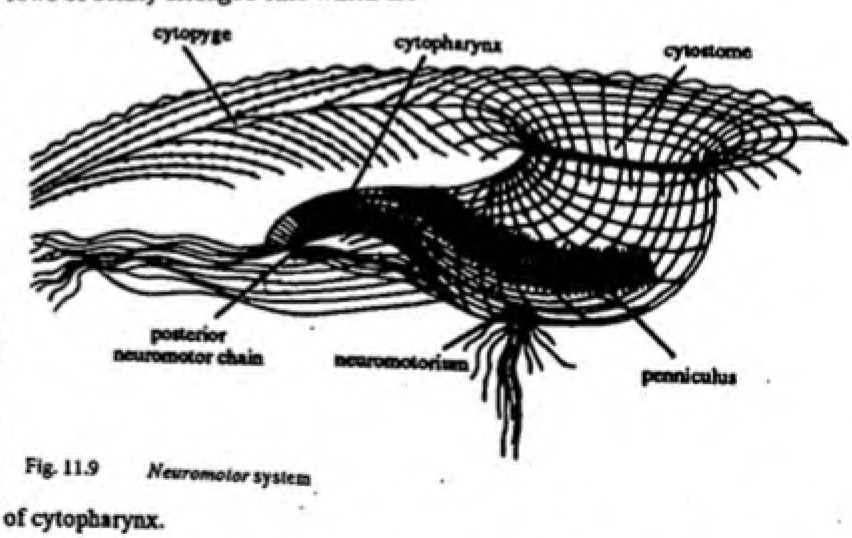

Fig. 11.9 *Neuromotor system*

The quadrulus and peniculi control food passage while endoral membrane guards the entrance of buccal cavity. A group of long cilia, *post buccal cilia* behind the lateral wall of cytopharynx.

Cytopyge. Just behind the cytostome on the ventro lateral surface there is a minute pore called *cytopyge.* Through this cytopyge the undigented food particles are eleminated out.

PHYSIOLOGY

Locomotion. The locomotion in *Paramecium* takes place by two methods:

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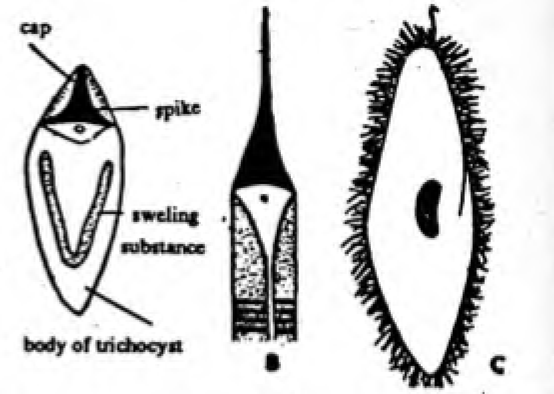

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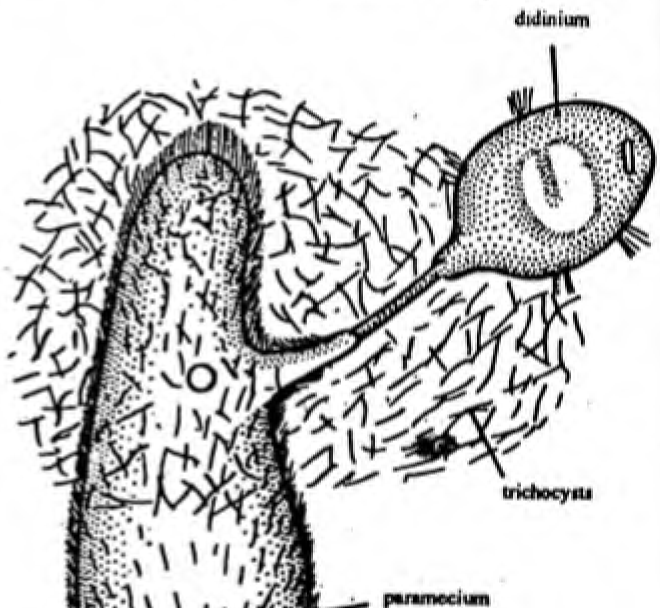

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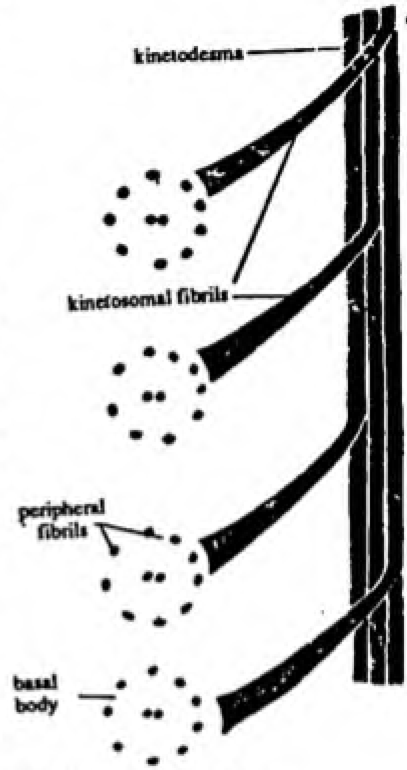

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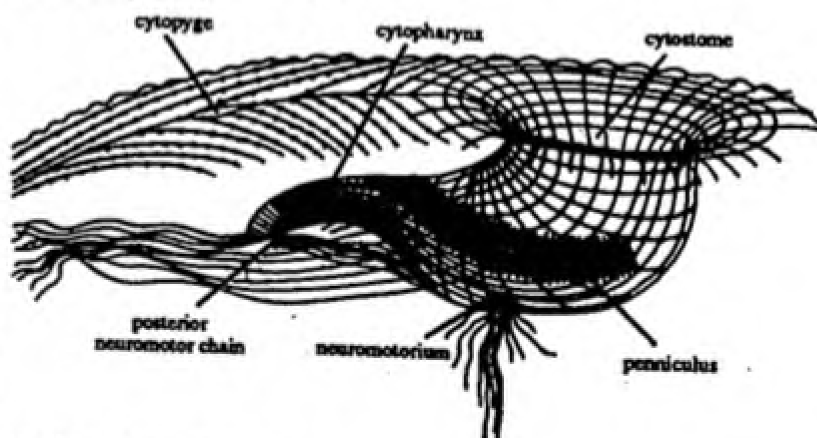

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PHYSIOLOGY

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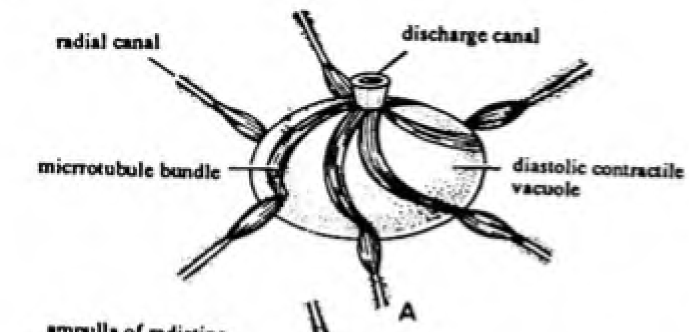


Fig. 11.10 Contractile vacuole of *Paramecium* A—during diastole, B—systole

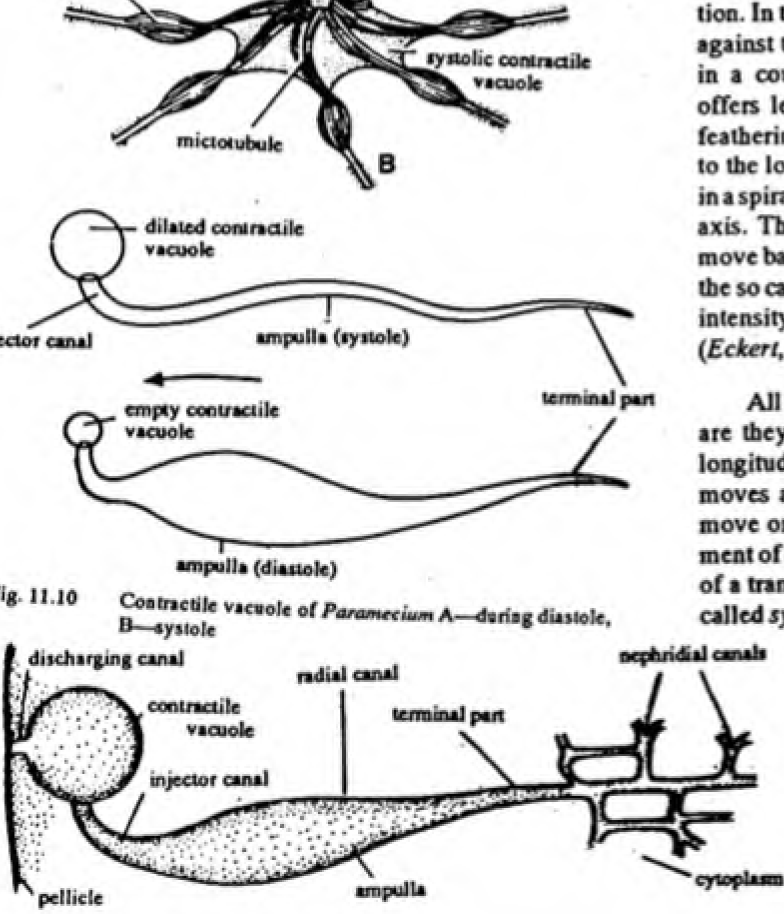


Fig. 11.11 Contractile vacuole of *Paramecium*

1. Cilliary locomotion

2. Metaboly

1. Ciliary locomotion. *Paramecium* swims in water by beating of its cilia and has put on speed because of development of a large number of these locomotary organs (10,000 - 18,000). It can swim very slowly, perhaps 5 meters per hour.

A cilium performs whip-lash movement by which water is propolled. In its beat each cilium performs an *effective* and a *recovery stroke.* During the effective stroke the cilium is outstratched and moves from a forward to a backward position. In the recovery stroke the cilium is bent over to the right against the body and is brought back to the forward position in a counterclock-wise movement. The recovery position offers less water resistance and is somewhat analagous to feathering an oar. The direction of effective stroke is oblique to the long axis of the body. This causes the animal to swim in a spiral path and at the same time to rotate on its longitudinal axis. The ciliary beat can be reversed, and the animal can move backward. This backward movement is associated with the so called avoiding reaction (behaviour). The direction and intensity of beat is controlled by levels of Ca++ and K+ ions (*Eckert*, 1972).

All the cilia of body can neither move simultaneously nor are they capable of independent movement. The cilia of a longitudinal row oscillate in such a way that the front cilium moves a little earlier than the one behind it. Thus the cilia move one after the other from front backwards. This movement of cilia is called *metachronal rhythm.* However, the cilia of a transverse row move simultaneously. This movement is called *synchronous rhythm.* The movement of cilia is controlled by the infra ciliary system and ATP plays an important role (*Serawin*, 1967).

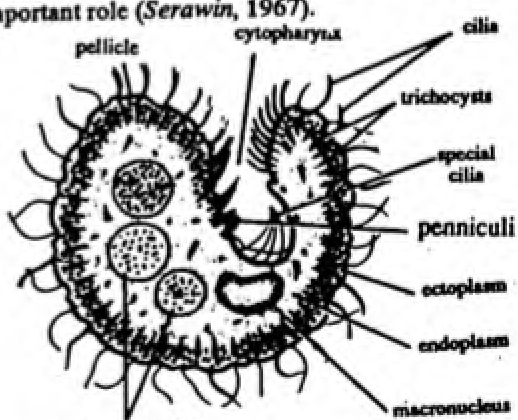


Fig. 11.12 T.S. of *Paramecium* through the region of cyto phory to show cilliation.

2. Metaboly. The body of *Paramecium* possesses elasticity. It can pass through a passage narrower than its body, after which it regains its normal size. Such type of movement is called *metaboly.* This type of body movement is caused by the cytoplasm.

Nutrition. The free-living ciliates are almost entirely *holozic.* It feeds on bacteria, small protozoan, yeast, algae etc. but its favourite food is *Bacterium coli.* It can devour 2-5 millian *Bacterium* in 24-hours. Thus *Paramecium* is a selective feeder, showing considerable choice of food, and often rejecting undigestible non-nutritive particles.

Feeding mechanism. It feeds while stationary or swimming slowly. In feeding, the cilia of the oral groove produce a current of water that sweeps in an arc-like manner down the side of body and over the oral region. The food particles are sucked with water current into the oral groove and then to the vestibule. Ciliary treat of vestibule direct the food particles into the buccal cavity. Some of these particles are discarded and left out. Quadrulus and peniculi regulate the passage of food into the cytopharynx. At the bottom of cytopharynx the food particles are gathered and form a rounded or ball-like mass, the *food vacuole*. It grows rapidly and when the vacuole attains a maximum size it is pinched off and takes its course in endoplasm. The food vacuole besides food particles also contains a little amount of water. The exect mechanism by which the food vacuole is liberated is not properly known probably post-oral fibres help in this process. The food vacuoles are formed in about 1-5 minutes depending upon the abundance of material and rate of feeding. The size of vacuoles depend upon the quantity and quality of food, viscocity of surrounding medium and the physiological state of individual.

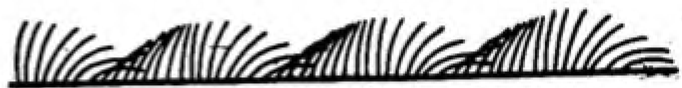


Fig. 11.13 A longitudinal row of *cilia* showing metachronal rhythm.

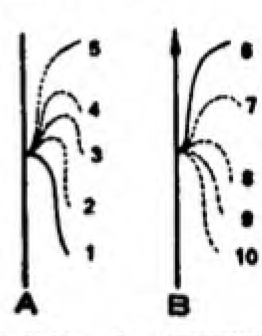


Fig. 11.14 A—recovery stroke, B—effective stroke

Digestion **and** ***Assimilation.*** The food vacuole thus formed move in the body in a definit path with the streaming movement of endoplasm. The movement of food vacuoles is called *cyclosis*. Soon after it enters the endoplasm the food vacuole moves, posteriorly up to the end where it stops momentarily and them turns dorsally and turning anteriorly it moves forwards. On reaching the anterior end of the body it moves back again along the oral side casting off unabsorbed remains. The food vacuole remains in the body from one to three hours.

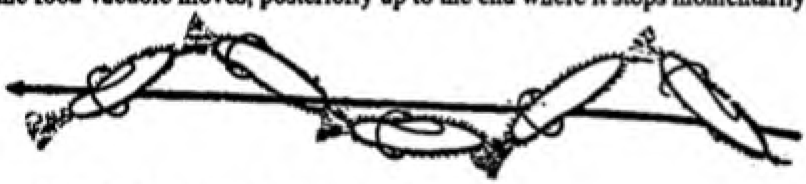


Fig. 11.15 Locomotion in *Paramecium*.

On leaving the cytopharynx the vacuole first decreases in size and finally increased. The decrease is due to osmotic concentration of endoplasm as it is higher than the vacuole, the water is lost from the vacuole and it becomes small.

The digestion of food takes place in the food vacuoles in which the medium is first acidic and later alkaline. As a result of digestion the proteins are hydrolysed into amino acids by *proteases*; carbohydrates into glucose by *carbohydrases*; and probably fat is also digested. The process of cyclosis can be demonstrated experimentally in *Paramecium*. If milk, coloured with *Congo Red* stain, is given to *Paramecium*, the fat particles of milk first become red due to the acidic reaction of the enzymes in food vacuoles, then they gradually turn purple and finally blue due to alkaline medium in the food vacuoles. Complete digestion takes place mainly during the later alkaline phase of food vacuole. The digested food materials are throughly distributed to all parts of body during cyclosis. Reserve food material is glycogen and fat-droplets which remain scattered throughout the endoplasm.

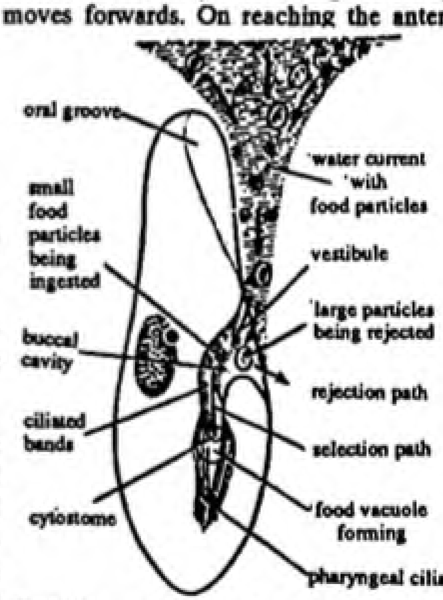


Fig. 11.16 *Paramecium* drawing water current to obtain food.

If *Paramecium* does not get food, it feeds upon the reserve food materials in the endoplasm. When even these are exhausted the macro-nucleus becomes smaller, the animal becomes transparent, vacuoles appear in the cytoplasm, cilia disappear and degeneration of specialized structures set in. This phenomenon is called *inanition*. It restores its normal shape when supplied with rich food such as bacteria.

Egestion. The vacuoles become smaller and finally the undigested food particles are released from the cytoproct or cytopyge into surrounding medium.

Paramecium bursaria displays symbiotic relationship with algae. The endoplasm is filled with green zoochlorellae. It takes its food material manufactured by zoochlorellae.

Respiration. Respiration takes place by diffusion through the general body surface. Oxygen is taken in and used for burning of food to obtain energy. As a result carbon dioxide is formed which is diffused out in surrounding water.

Excretion. Most of the nitrogenous excretion in *Paramecium* is carried by diffusion through general body surface. Contractile vacuoles also serve for excretion as urea has been detected in them. The chief nitrogenous product is ammonia which is diffused out.

Osmoregulation. Two contractile vacuoles regulate the water content of the body. They occupy rather fixed position, one being anterior and the other posterior. Each vacuole is surrounded by 5-12 radiating canals. Both vacuoles derive energy to work from the mitochondria crowded around them.

Behaviour. *Paramecium* is extremely sensitive to different types of stimuli and shows its reaction to them. The response is positive when the animal moves towards a stimulus and negative when it moves away. To an adverse stimulus the animal continuous to give the avoiding reaction until it escapes. Various stimuli and their response given by *Paramecium* are:

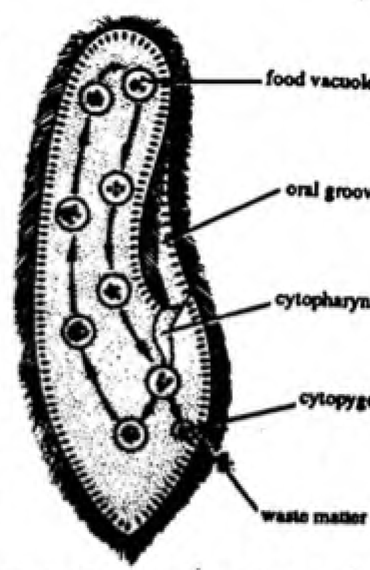


Fig. 11.17 *Paramecium* showing cyclosis

1. *Reaction to mechanical stimuli (Thigmotaxis or Thigmotropism).* Response to contact is varied. If the anterior end lightly touches a fine point, the animal shows strong avoiding reaction. A slow moving individual responds positively to contact with an object by coming to rest upon it.

2. *Reaction to temperature (Thermotaxis or Thermotropism).* The optimum range of temperature for paramecia is 24-28°C, but they can withstand considerably lower and higher temperature than the optimum range. Extreme cool and hot water is avoided.

3. *Reaction to chemical (Chemotaxis or Chemotropism).* It shows avoiding reaction to chemical like base. If a drop of weak salt solution (.5%) is introduced in a *Paramecium* culture on a microslide, the animal show negative response. However, they show a positive response to the acids.

4. *Reaction to light (Phototaxis or Phototropism).* It shows negative response to bright light as well as dark. It responds to the diffused light. However, *P. bursaria* is positively phototactic.

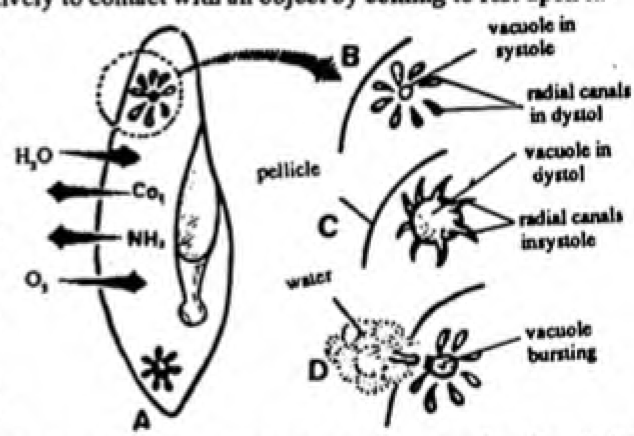


Fig. 11.18 *Paramecium* diagrametic representation of respiration, excretion and osmoregulation.

5. *Reaction to gravity (Geotaxis or Geotropism). Paramecium* generally exhibit a negative response to gravity as seen in a culture contained in a test tube where they gather close to the surface film with their anterior ends pointed upward. If paramecia are introduced in an inverted water filled 'U' shaped tube stoppered at both the ends, they immediately move upward into the horizontal part of the tube.

6. *Reaction to water current (Rheotaxis or Rheotropism).* In a gentle water current the paramecia will mostly move with the flow with their anterior ends upstream thus showing positive response.

7. *Reaction to electric current (Galvenotaxis or Galvenotropism).* When two electrodes are placed opposite each other in a shallow dish containing paramecia and a constant current applied all the organisms swim towards the cathode.

8. *Reaction to hydrostatic pressure (Barotaxis or Barotropism).* When the hydrostatic pressure is increased, the rate of movement is decreased.

REPRODUCTION

Ciliates differ from almost all other organisms in possessing two distinct types of nuclei-a-usually large macronucleus and one or more small micronucli. They are diploid with little RNA. The micronucleus, a store of genetic material, is responsible for

genetic exchange and nuclear organization, and also gives rise macronucleus.

In *Paramecium* two types of reproduction is reported.

I Asexual Reproduction

II Sexual Reproduction

I Asexual Reproduction

Asexual reproduction takes place during favourable conditions. Asexual reproduction is always by means of binary fission, which is typically transverse. More accurately, fission is described as being homotheogenic, with the division plane cutting across the kineties-the longitudinal rows of cilia.

Before the beginning of fission, *Paramecium* stops feeding and the body elongates to become spindle-like. The oral groove disappears. The micronucleurs divides by the complicated process of mitosis and the resulting two daughter micronuclei move towards opposite ends of the cell. All the stages of mitosis i.e. prophase, metaphase, anaphase and telophase take place inside the nuclear membrane. The number of chromosomes is 36-150 depending upon the species. When this is happening, the macronucleus also elongates, divide transversely by amitotic process in which the number of chromosomes may differs. A transverse constriction appears in the middle. The constriction deepens gradually. In the mean time two oral grooves begin to form one in the anterior half and another in the posterior half. Two original contractile vacuoles of parent remain, one in each half of the dividing parent individual. Two contractile vacuoles are later formed. Two new buccal structures also appear. Now the constriction completely divides the parent into two daughter paramecia of equal size and with a complete set of cell-organelles. These grow to full size before dividing again.

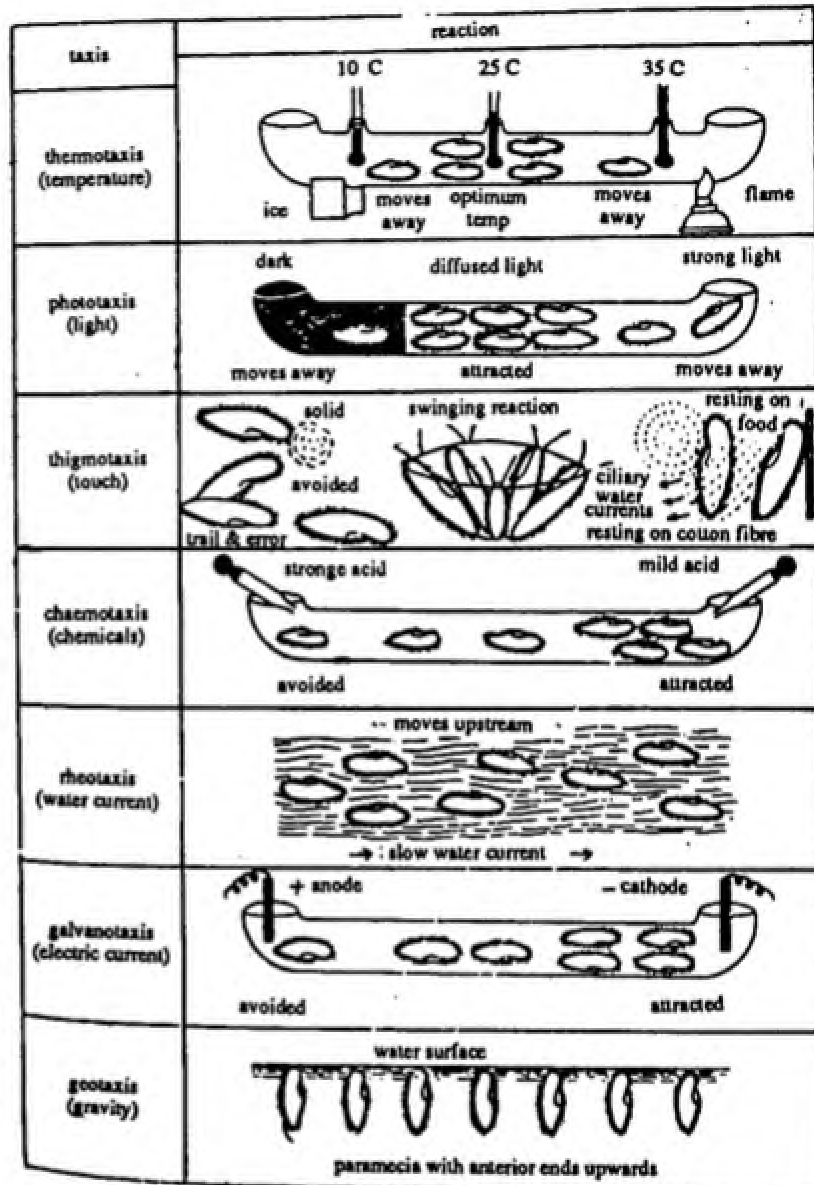


Fig. 11.19 *Paramecium* showing response to various stimuli

The newly formed daughter paramecia neither resemble each other nor the typical parent, so that for a while they can be distinguished as the anterior daughter (*Proter*) and the posterior daughter (*Opisthe*). Soon they assume the typical form.

The entire process of binary fission is completed within 30-120 minutes depending upon the availability of food and temperature. In *P. caudatum* it may occur 2-3 times a day and in *P. aurelia* about 5 times a day, so that a large number of them can be obtained in a short time. All the individuals which are produced from a single parent, collectively, form a *clone* and all the members of a clone are genetically alike.

The binary fission cannot go on indefinitely. After several generations, the rate of fission declines.

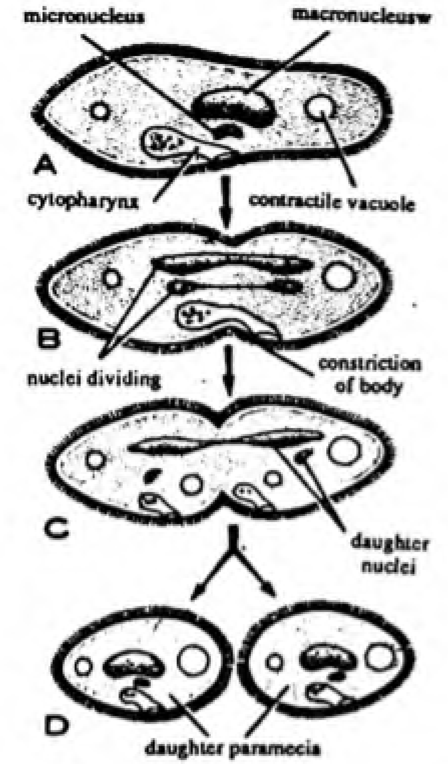


Fig. 11.20 *Paramecium Caudatum* showing binary fission

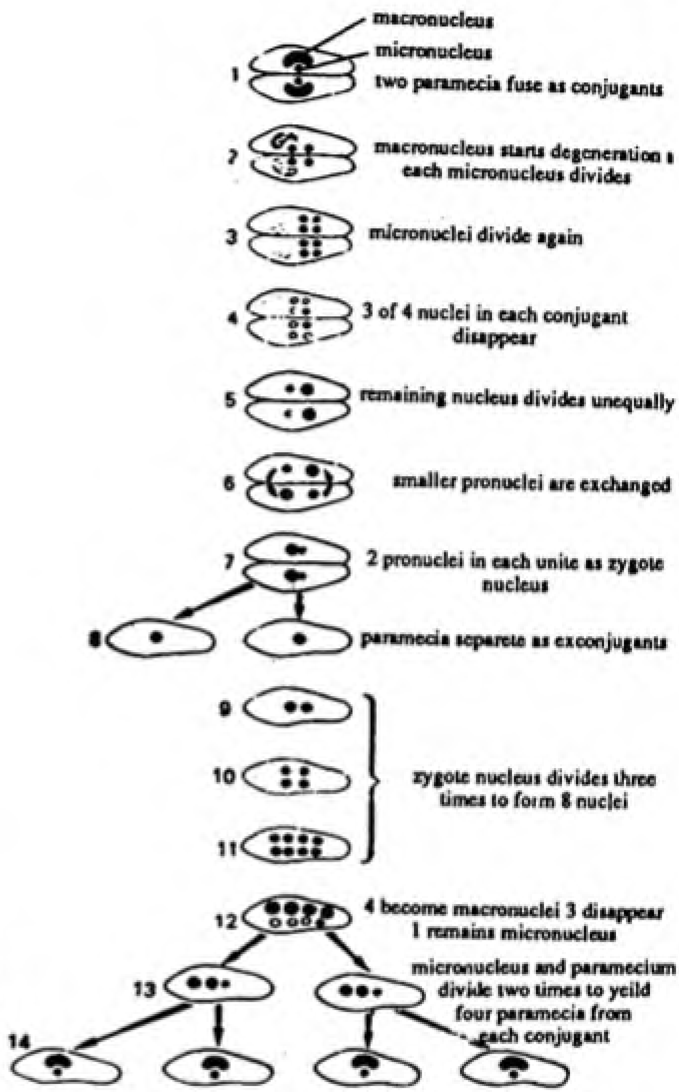


Fig. 11.21 *Paramecium caudatum* showing stage of conjugation

II Sexual reproduction

Paramecium reproduces sexually in which nuclear material of two individuals is interchanged. This method is called *conjugation*, but it is simply a temporary union of two individuals of one and the same species.

Process of Conjugation. The process of conjugation is given by *Hertwigg* and *Maupas* (1889) in *P. aurelia*. The basic pattern is similar with slight variations in different species of *Paramecium*. Here we will discuss the process of conjugation in *P. caudatum*.

At the beginning of conjugation two ciliates come together and become attached first at deciliated areas near the anterior end of their ventral surfaces, and later by attachments formed in the gullet region where membrane fusion leads to the formation of a number of pores providing cytoplasmic bridges between them. Now they are called *conjugants*. Adhesion probably takes place by the secretion of a sticky substance produced by the cilia. Attachment lasts for several hours.

The macronucleus of each conjugant starts disintegrating. It simply breaks up into pieces which are digested in cytoplasm. The micronucleus of each conjugant now grows in size and divides twice, the first division being meiotic result in the formation of 4 haploid nuclei.

Three micronuceli degenerate and disappear from cytoplasm of each conjugant leaving behind one nucleus. The remaining nucleus divides again unequally forming one bigger and other smaller nuclei. The smaller nucleus is active and called ***migratory*** or *male pronucleus*. The bigger one is inert and called *stationary* or *female pronucleus*.

The male pronucleus of one conjugant passes into the other conjugant through the protoplasmic bridge, similarly the male pronucleus of other conjugant passes into the first conjugant. Now the male and female pronuclei fuse results in the formation of *zygote nucleus*. The complete fusion of two nuclei from two different individuals forming a zygote nucleus is called *amphimixis*. The process cannot be called as fertilization because there is no fusion of gametes and their cytoplasm.

After about 12 hours or so the conjugants are separated and are now termed as *exconjugants*. The zygote nucleus divides thrice in each exconjugant resulting 8 nuclei. The divisions are mitotic. Out of these 8 nuclei 4 assume large size and become macronuclei. Remaining 4 are micronuclei. Out of these 4 micronuclei 3 disappear leaving behind only 1 micronucleus. It divides again forming two and at the same time the exconjugant divides by binary fission into two cells. Each cell having two macronuclei and one micronucleus. The micronucleus again divides into two micronuclei and at the same time the cell divides into two daughter paramecia by binary fission. Each daughter having one macronucleus and one micronucleus.

Thus each conjugant produces four daughter individuals in the end of conjugation. The whole process of conjugation takes about 96 hours to complete.

Factors and Conditions of Conjugation

Conjugation is unique type of a sexual process in which following conditions and factors one necessary.

1. Conjugation takes place after a desirable number of asexual reproduction i.e. about 300 generations which have reproduced by binary fission or it occurs after a long continuance of binary fission so that the rejuvination may take place in the exhausted or perishing clone.
2. Conjugation occurs when changes take place in the physiological condition. The individuals are usually smaller in size (210μ in length) than the normal individuals.
3. It occurs during unfavourable conditions such as scarcity of food, light etc.
4. Agglutination favours conjugation. It is a sticky substance secreted by cilia of conjugants.
5. Conjugation starts early in the morning and is continued till the afternoon. It suggests that dark favour conjugation and light supress it.
6. Conjugation never takes place among the individuals of a clone. It occurs between the individual of a *variety* or *syngen* belonging to two different *mating types*. Since each syngen has two mating types.

   In *P. caudatum* there are 16 syngens and 32 meting types.

Significance of Conjugation

The significance of conjugation has been discussed in details, but it still remains uncertain. The following significances are attributed to conjugation.

1. It is the method of *rejuvination* by which the vigour of the species is maintained. If conjugation does not occur for a long time than paramecia become weak and ultimately die.
2. Conjugation is a temporary union in which there is no mixing of cytoplasm of the conjugants but a zygote nucleus is formed by the fusion of their nuclei, therefore, the zygote nucleus of each conjugant possesses the herediatary material of both the conjugants i.e. new characters come in them.
3. In conjugation, the macronucleus is replaced by the material of zygote nucleus. The number of chromosomes is restored in macronucleus by conjugation due to which the vigour of daughter paramecia is renewed.
4. The function of micronucleus is to maintain balanced chromosomes and gene complex.

Aberrant behaviour in reproduction

Paramecium shows certain variations in its nuclear behaviour during fission and conjugation these deviations are *Autogamy, Endomixis, cytogamy* and *Hemixis*.

According to *Sonneborn* (1957) in *P. aurelia*, there are 14 syngens and 28 mating types. These are as follows.

Table. Shwoing the mating types of *P. aurelia* complex -

Syngenr number	*Mating type*	*Other mating types with which conjugation occurs (and %)*	*Group*	*+ or - type*
1	I	II (95%), X (40%)	A	-
	II	I (95%), IX (40%), XIII (10%), V (1%)		+
2	III	IV (95%)	B	
	IV	III (90%)		
3	V	VI (95%), XVI (40%), II (1%)	A	-
	VI	V (95%)		+
4	VII	VIII (95%), XVI (95%)	B	-
	VIII	VII (95%), XV (60%)		+
5	IX	X (95%), II (40%)	A	-
	X	IX (95%), I (40%		+
6	XI	XII (95%)	B	-
	XII	XI (95%)		-
7	XIII	XIV (95%), II (10%)	B	-
	XIV	XIII (95%)		+
8	XV	XVI (95%), VIII (60%)	B	-
	XVI	XV (95%), VIII (95%), V (40%)		+
9	XVII	XVII (95%)	A	-
	XVII	XVII (95%)		-
10	XIX	XX (95%)	B	-
	XX	XIX (95%)	A	-
11	XXI	XXII (95%)	A	
	XXII	XXI (95%)		
12	XXIII	XXIV (95%)	B	-
	XXIV	XXIII (95%)		+
13	XXV	XXVI (60%)	C	-
	XXVI	XXV (60%)	C	-
14	XVII	XXVIII (95%)	A	-
	XXVIII	XXVII (95%)		+

1. ***Autogamy***. *Diller* (1934, 36) described a process of self-fertilization or *autogamy* occuring in a single individual of *P. aurelia.* About once a month *P. aurelia* undergoes this process.

During autogamy the macronucleus increases in size to form an irregular structure and later breaks up into small fragments are absorbed in the cytoplasm. The two micronucli divide twice forming eight nuclei. As a rule the first division is meiotic thus all the eight nuclei are haploid. Out of these eight nuclei, seven disintigrate and only one nucleus is left. It again divides to form two nuclei. These nuclei are called gametic nuclei. By this time a peculiar cone-like bulge appears on the surface of autogamous animal, slightly to the right and anterior to the cytostome. Because of its position it is called the *oral cone* or *protoplasmic cone.* The gametic nuclei are at first elongated and spindle like bodies. Often there is slight size variation between them so that they may be termed to as *male* (smaller) and *female* (larger). They approach each other and then move into the cone and fuse to form zygote nucleus. Later it comes out of cone and the cone disappears. The zygote nucleus divides twice forming four nuclei. Two of these nuclei increase in size to become macronuclei and remaining two as micronuclei. The cell body and micronuclei divide by binary fission to form two daughter paramecia each with a macronucleus and two micronuclei.

Signiflfance of Autogamy

1. Rejuvination in the species is accomplished by autogamy.

2. A new macronucleus is formed from the material of micronuclei.

3. *Paramecium* regains its lost vigour by this process.

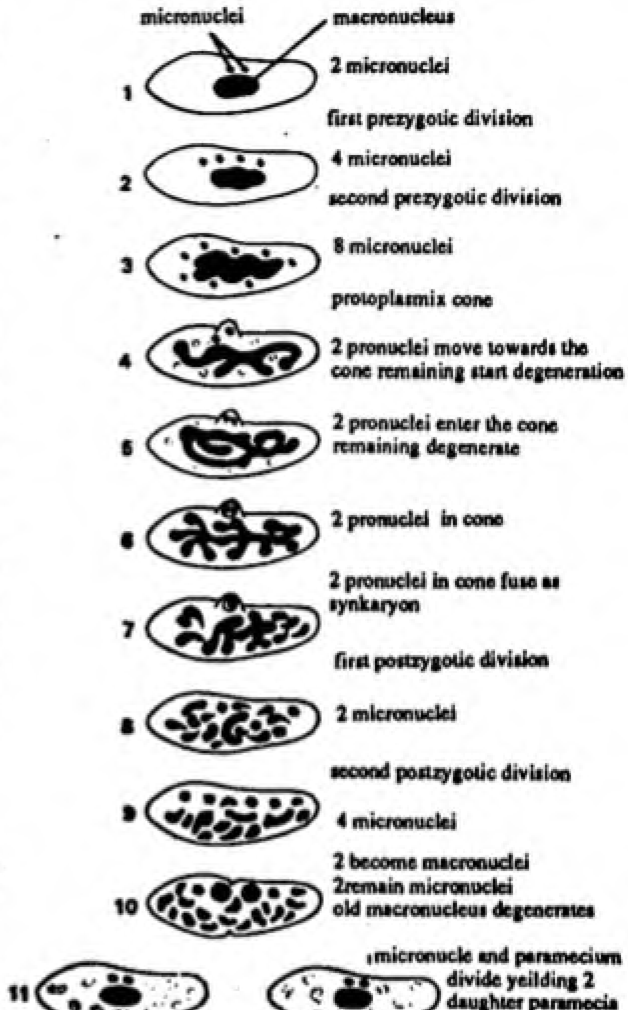


Fig. 11.22 *Paramecium aurelia* showing various stages of autogamy

2. ***Endomixis.*** Endomixis was first observed by *Woodruff* and *Erdmann* (1914) in *P. aurelia.* In endomixis only the nuclear reorganization occurs after which the body of *Paramecium* divides into daughter paramecia. It occurs as follows:

When endomixis starts, the macronucleus disintigrates and disappears. The two micronuclei divide twice resulting in the formation of eight nuclei (all diploid). Out of these 8 nuclei six disintigrate and only two are left. Now the *Paramecium* divides by fission into two daughters each with one nucleus. The nucleus of each daughter divides twice forming four nuclei. Two nuclei enlarge to form macronuclei and remaining two micronuclei. The two micronuclei, again divide to form four micronuclei in the mean time the cell divides again by fission into two daughters each containing one macronucleus and two micronuclei. In the end four daughter paramecia are formed from one individual.

According to *Diller* (1936), *Sonneborn* (1947) and *Whichterman* (1953) the endomixis does not occur in *Paramecium.*

3. ***Cytogamy.*** *Wichterman* (1940) observed the process of cytogamy in *P. caudatum.* The process is something intermediate between conjugation and autogamy. Two individuals stick by their oral surfaces, the micronucleus divides twice (first division in meiotic) of these three disintegrate into the cytoplasm, the remaining one divides once producing two gametic nuclei. Self-fertilization takes place. The conjugants now separate and called exconjugants. Exconjugants behave and multiply as in conjugation. The process is completed in about 13 hours.

The genetical consequence of cytogamy is always homozygosity.

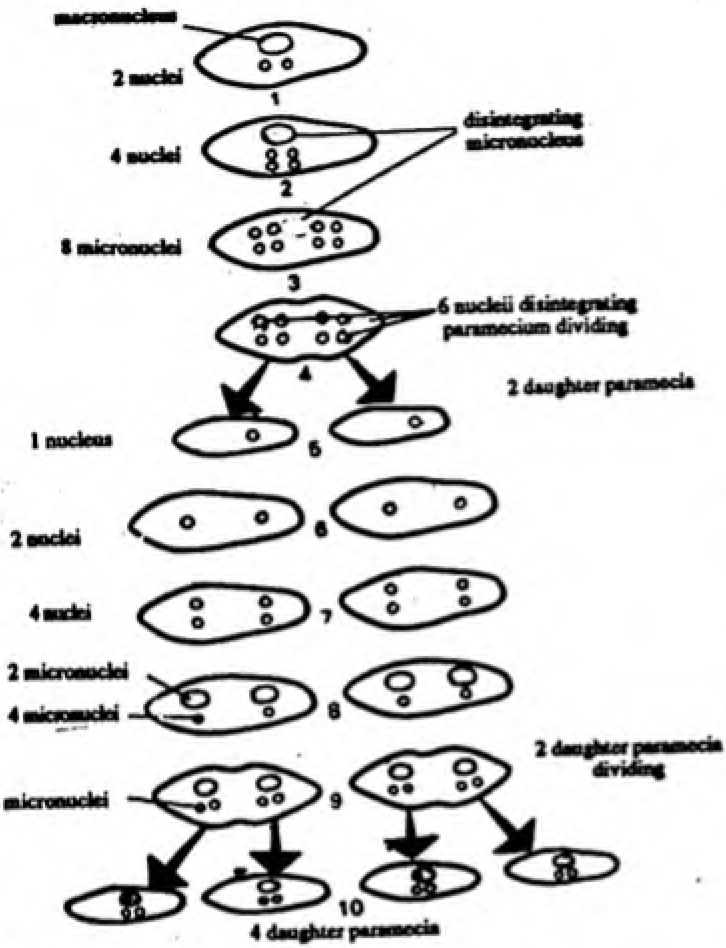


Fig. 11.23 *Paramecium aurelia* showing endomixis.

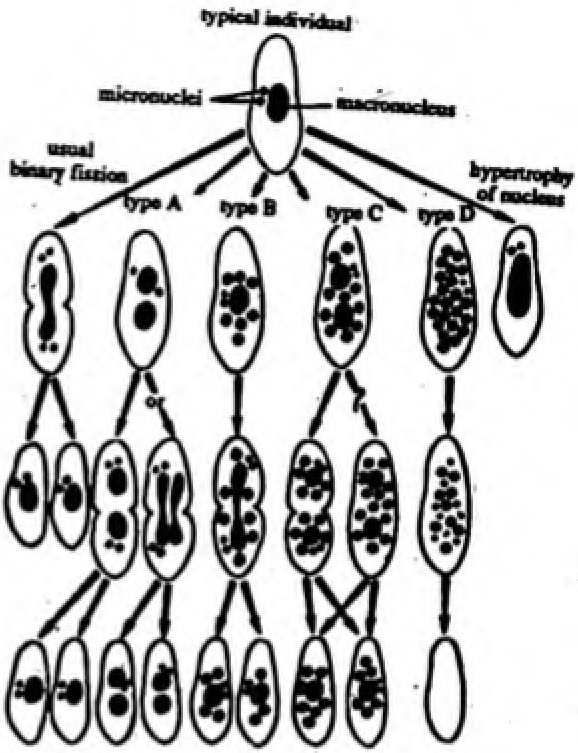


Fig. 11.24 *Paramecium aurelia* showing hemixis.

4. ***Hemixis.*** This method of nuclear reorganization was observed by *Hartman* in *P. aurelia* and was supported by *Diller* (1936). During hemixis the micronucli do not participate. The macronucleus throws out two or more equal or unequal fragments to be absorbed in the cytoplasm. The remainder of macronucleus and micronuclei behave normally at the cell division.

   Diller classified hemixis into four types.

1. *Type A.*, It is the simplest form of hemixis characterized by a division of the macronucleus into two or more parts in the cytoplasm.
2. *Type B.* It is characterized by the extrusion of 1-20 or more chromatin balls from the macronucleus.
3. *Type C.* It is characterized by the simultaneous splitting of macronucleus into 2 or more major portions and extrusion of balls into cytoplasm.
4. *Type D.* It is considered to be the pathogenic conditions in which micronucleus undergoes complete fragmentation into chromatin balls that disappear from the cell later on. Micronuclei generally disappear before the dissolution of macronucleus.

The hemixis is considered as an act of purification on the part of the macronucleus and the process of chromatin material cast off by it are held in contain waste and harmful substances.

Killer Paramecia

Sonneborn discovered that certain strais of *P. aurelia* liberate a toxic substance into the medium in which they live. This

toxic substance kills the other strains of *Paramecium*. He called the former strain as *killers* and later as *sensitives*. The toxic substance is named as *parmecin*. The killing takes place slowly, the sensitive taking about two days to die.

Symbiotic bacteria (*Caedibacter*) have been found living in the cytoplasm of *P. aurelia* (*Soldo*, 1974; *Preer*, 1981) and have been given such names as kappa, mu, pi, lambda etc.; lambda possess bacteria flagella, and several types of symbiont have bacterial cell walls, killer paramecia were found to contain kappa, but the persistance of kappa in the cytoplasm was dependent upon the presence of dominant macronuclear gene. Only kappa bodies that contained refractile inclusions (tightly-coiled ribbons associated with virus-like granules) were able to kill, but other kappa could develop these inclusions. Other symbionts act in a comparable manner; paramecia that possess mu kill sensitive at conjugation (they are mate killers), while pi may be inactive kappa. Paramecia that contain lambda produce lethal granules which are released into the medium. It is assumed that these symbionts derive nutrients from the paramecia. A killer stock has an advantage over a sensitive stock in ecological competition (*Landis*, 1981). Lambda apparently synthesises folic acid, and paramecia with this symbiont have no external requirement for this vitamin.

12

NUTRITION IN PROTOZOA

The process by which an organism takes in food, digest it and assimilate it is known as *nutrition*.

There are different methods by which protozoa take their food, because food provides energy to organism to make-up for the wear and tear of body components lost during its manifold activities. Following types of nutrition takes place in protozoa:

(1) Holozoic

(2) Holophytic

(3) Saprophytic or Saprozoic

(4) Parasitic

(5) Mixotrophic

(6) Coprozoic

1. *Holozoic nutrition*

Holozoic (Gr. *holos* = whole; *zoon* = animal), as the name indicates animal like. All the higher animals obtain their nourishment by this method. They depend upon ready-made food. This ready-made food is either small organism or plant. The nutrition involves into the capturing of food, its ingestion, digestion and assimilation, and rejection of waste undigested products.

Food capturing and ingestion. The methods of food capturing is different in different species of different classes. The locomotory organelles play an important role for capturing the food. But in addition to it there are few other structures which also help in this process.

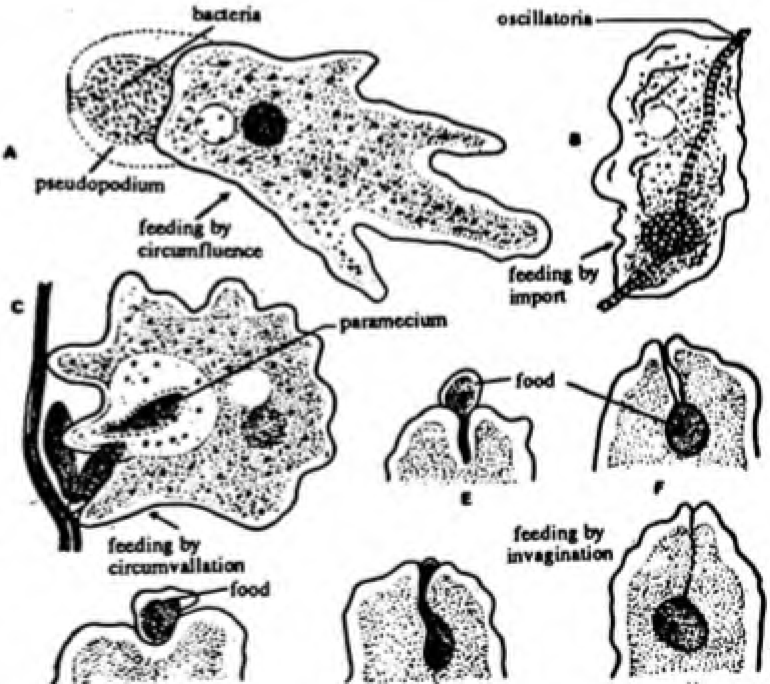


Fig. 12.1 Ingestion in *Amoeba*. A—by circumfluence, B—by import, C—circumvallation, D-H—by invagination.

In Sarcodina:

The mouth is totally absent so that food is ingested at any point of body surface. According to *Rhumbler* (1910) four types of food ingestion occur in *Amoeba* namely :

(i) ***By import.*** In this method the food is taken into the body upon contact with very little movement on the part of animal. For example, the algal filament is taken inside the body by *Amoeba verrucosa*.

(ii) ***By circumfluence.*** The cytoplasm of body flows around the prey and engulf it, the prey is usually immobile like bacteria.

(iii) ***By circumvallation.*** The method is employed when the prey is active. The pseudopodia flow down from the body which surround the prey and engulf it. The engulf part contains a lot of water and prey. This forms a food vacuole.

(iv) ***By invegination.*** Upon touching a food particle, the ectoplasm shrinks and inveginates into endoplasm forming a food tube. The food particle with a drop of water flows into the tube, the ectoplasm beals up behind it.

The radiolarian and heliozoans capture food with their axopodia which are retracted, along with the prey, into the cytoplasm. In *Elphidium*, organisms adhere to the reticulopodia are parlysed and then ingested in reticulum outside the shell.

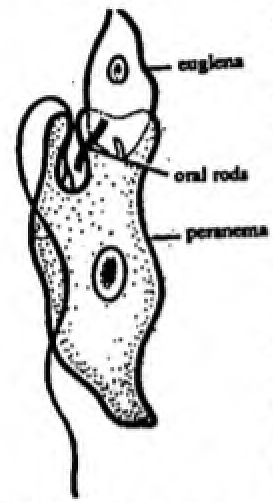


Fig. 12.2 *Paranema* feeding on *Euglena*

In Mastigophora:

They generally bear a cytostome which open into the endoplasm by means of a tubular cytopharynx as in *Euglena*. By the lashing movement the food-particles are directed into the cytostome. The method of ingestion in *Paranema* is observed by *Chen* (1950). *Paranema* traps *Euglena* by first harpooning the victime with its oral rods. The flagellum beats actively which contacts the body, followed by elongation. This process goes till the *Euglena* comes wholly in the body of *Paranema*.

In Ciliata:

There are many types of cytostomes and associated structures, but the food capturing seems to be of two types. In some ciliates the cytostome remains permanently open e.g. *Paramecium*. It is a continuous feeder. The food particles are small in size that pass through the cytostome and goes into endoplasm. In another kind the cytostome remains closed e.g. *Coleps* and *Didinium*. The cytostome opens only when a prey is to be ingested (*Kidder* and *Dewey*, 1940). In reptorial ciliates like *Porodon* a circlet of trichites surrounds the cytostome. The cytostome leads into cytopharynx. The cytopharynx is ciliated which creates water current and allows to bring food particles with water. Trichocysts of *Paramecium* and myoneme of *Vorticella* also help in ingestion of food.

In Suctoria:

In some suctorian the tubular tentacles help in ingestion of food. The tips of these tentacles are devoid of pellicle and possess haptocysts which pierce into the body of the prey. They suck liquid and solid materials as in *Choanphrya*. The tentacles also secrete toxic substance which paralyses the prey.

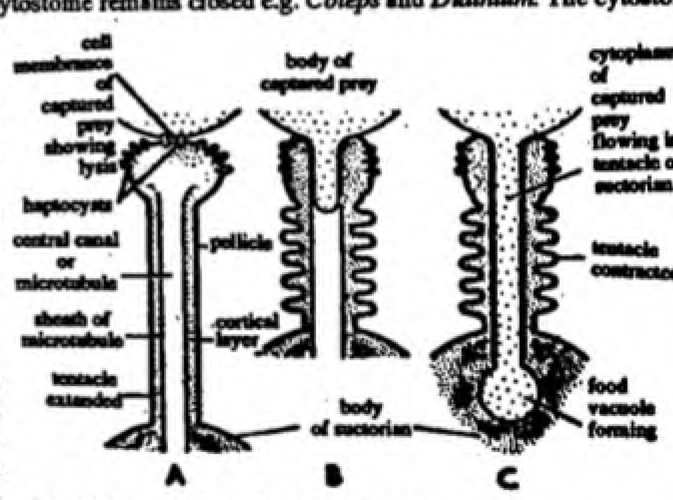


Fig. 12.3 Feeding by hollow tentacle in a *Suctorian*

Digestion and Assimilation

The food vacuoles contain ingested particles are usually surrounded by water. The quantity of water vary in different vacuoles. The food vacuoles finally reach in the endoplasm. In *Amoebina* the vacuoles are carried about by the moving endoplasm. In ciliates the fluid endoplasm shows streaming movement called cyclosis. In *Vorticella* species food vacuoles are formed one by one at the end of cytopharynx migrate throughout the cytoplasm. The old vacuoles disintegrate at the base of cytopharynx and thence to out side (*Hall*, 1931).

The motile or active prey which is taken in by the protozoa losses its movement and finally dies. It is believed that acid, alkalies and digestive enzymes are poured in food vacuoles (*Engelmann*, 1878, *Brandt*, 1881). According to *Nirenstein* (1925) the food vacuoles of *Paramecium* undergo in changes in reaction first acidic and then alkaline. On the other hand *Khainsky*

(1910) observed that the food vacuoles of *Paramecium* is acidic during the entire period of protein digestion; becomes neutral and finally becomes alkaline when the solution of food substance is ended. *Shapiro* (1927) studied the reaction changes in food vacuoles of *Paramecium caudatum* by using phenol red, Congo red and neutral red. Various types of enzymes are produced by different protozoa. viz. in *Amoeba proteus*, peptidase (observed by *Holter* and *Kopac*, 1937) protienase observed by *Anderson* and *Holter*, 1949) and amylase (by *Holter* and *Doyle*, 1938). In *Paramecium caudatum* peptidase and amylase enzymes are observed by *Holter* and *Doyle* (1938). They can also digest fat (*Dawson* and *Belkin*, 1928) and even cellulose. *Cleveland et al.* found that many symbiotic Hypermastigina (*Trichonympha*) and Polymastigina (*Colonympha*) living in the intestine of termites, cattles and horses can digest cellulose. In *Tetrachymena* the lysosomes provide glucosidases, proteases, amylase, phosphatase and enzymes digesting nucleic acids.

The digested food is supplied to every part of body by diffusion from the food vacuoles. *Roth* (1960) studied digestion in *Pelomyxa* under electron microscope during alkaline phase. He suggestes that the transfer of the digested materials from the vacuole into the cytoplasm is by formation of pinocytic vesicle around the food vacuole which gradually disintegrates in the cytoplasm, liberating their nourishing content.

Egestion

The undigestible residue of the food is thrown out by the body. In Sarcodina egestion of residue may takes place at any point of body; but in pellicle bearing forms, the egestion takes place through the cytopyge present on the posterior region of body or through the vestibule (*Carchesium*). Permanent cytopyge is absent in some forms. The permanent cytopyge bearing ciliates are *Balantidium* and *Nyctotherus*.

2. Holophytic nutrition

(Gr., *Holes* = whole; *phyton* = plant) as the name indicates plant-like nutrition. In this process the animal, like plants, decompose carbon dioxide by means of chlorophyll contained in chromatophores, in the present of light, so as to form carbohydrate with the liberation of oxygen. The animal forms a special type of starch called paraglycogen. In a number of other cases the organism itself is without chromatophoses but is apparently not holozoic, because of the presence of chlorophyll bearing organisms within it. For example in the testacean, *Paulinella*, absence of food vacuole but chromatophores of peculiar size are present. *Paulinella* appears to be a species of algae which holds a symbiotic relationship with the testacean. In *Paramecium burseria* and *Stentor polymorphus* the chromeatophores are absent but they are also not holozoic. They are able to obtain nourishment with the aid of symbiotic algae, Zoochlorellae, in the cytoplasm.

3. Saprozoic nutrition

(Gr., *Sapros* = rotten; *zoon* = animal). This type of nutrition is seen in many parasitic protozoa, and colourless, free-living flagellates. The organic food materials are dissolved in water. The organism does not possess any special organ for the ingestion. The ingestion takes place through the body surface by the process of diffusion. *Pringshein* (1937) observed in *Polystomelia* that sodium acetate is needed from which the starch (among others) is produced and carbohydrates have no direct bearings upon the nutrition.

The complicated system of food vacuoles, called *pusule*, found in dinoflagellates (*Ceratium*) is the example of special organelles employed for saprophytic nutrition, since they are filled with decomposed organic matters.

4. Parasitic nutrition

The protozoa which live within the body of another organisms or hosts are able to nourish themselves by absorbing the digested or decomposed food of the host is termed as parasitic nutrition.

According to the type of food substances, the parasitic protozoan are of two types;

(i) ***Food robbers***. The protozoa of this category feed on the digested food material found in the alimentary canal of the host by holozoic manner e.g. *Balantidium* and *Nyctotherus* or by saprozoic method e.g. *Opalina*. They are usually commensels.

(ii) ***Pathogenic***. The protozoa of this category feed on the living tissues of the host and cause different types of diseases. *Entamoeba histolytica* obtain food by holozoic manner, and *Plasmodium* and *Trypanosoma* employ saprozoic method.

5. Mixotrophic nutrition

Some protozoa utilize more than one method of obtaining nutrients. The common example is *Euglena gracilis*. According to *Zumstein* (1900) and *Lwoff* (1932) *E. gracilis* losses green pigments in dark. This indicates that it can survive without chlorophyll by saprophytic nutrition. *Entamoeba histolytica* engulfs RBC and tissue fragments holozoically and dissolves host cells by enzymes it secretes. The dissolved material is than absorbed saprozoically.

6. Coprozoic nutrition

Many free-living protozoa feed upon the faecal matter of other organisms and are teamed coprozoic. e.g. *Rhymchomonas nasuta, Chlamydophrys stercorea* etc.

RESERVE FOOD MATERIALS

By the anabolic activity of organism result in growth and increase in volume, and also in the formation and storage of reserve food material. The reserve food material is glycogen, paraglycogen, certain crystals etc. These are used during scarcity of food material or growth or reproduction.

The anabolic product of holophytic nutrition are starch, paramylon, oil and fats. The paramylon bodies of various sizes among different species but in a given species they are similar. These are insoluble in boiling water but soluble in concentrated sulphuric acid, potassium hydroxide etc. It does not stain with iodine or zinc chloride.

Fat occurs widely in protozoa as globules. *Zingher* (1934) found that in Sarcodina and Ciliata each species shows morphological characteristic in having the fat. In *Amoeba* and *Pelomyxa* abundant fat bodies occur which can be seen with staining Sudan III.

Volutin occurs in every protozoa except Ciliophora. *Reichenow* and others hold that volutin appears to be a free nucleic acid and is special reserve material for the nuclear substance. *Sassuchin* (1935) studied the volutin in *Spirillum volutans* and found that during strong period of growth, nourishment and multiplication they increase but disappear in unfavourable conditions of nourishment and gives a series of carbohydrate reactions.

13

REPRODUCTION IN PROTOZOA

In many protozoa, reproduction occurs at frequent intervals, with relatively short period of growth intervening under favourable conditions. In some cases growth may extend over a period of several to many days so that reproduction occurs at long intervals.

In the less complex protozoa many modes of reproduction are seen. In some they are very simple while others they are much complex. In either case they are essentially similar to the cell-divisions as seen in higher animals and always begin with the division of nucleus.

Basically reproduction in protozoa takes place by two distinct methods;

I. Asexual Reproduction

II. Sexual Reproduction

I. Asexual Reproduction

In asexual reproduction, no specialized sex cells are involved. The stage of asexual reproduction is found in all the groups of this phylum. Even those protozoa which reproduce sexually also multiply by asexual processes. Generally the asexual reproduction is of the following types:

1. Binary Fission
2. Multiple Fission
3. Plasmotomy
4. Budding.

1. **Binary Fission.** This is the most common type of reproduction found in protozoa. Here division of parental cell into two or more daughter cells occur. The nuclear division is mitotic (*Karyokinesis*) followed by the division of cytoplasm (*cytokinesis*) by a constriction.

The plane of the division of the cytoplasm of the body varies in different groups of protozoa. On the basis of this, binary fission is of the following types:

(i) ***Simple binary fission.*** Here the plane of division cannot be definitely ascertained because no special event takes place at the time of division. Simple binary fission occurs in Sarcodina (*Amoeba*).

(ii) ***Longitudinal binary fission.*** In flagellates and peritrichous ciliates (*Vorticella*) the plane of division is parallel to the longitudinal axis of the body.

(iii) ***Transverse binary fission.*** In Cilophora (*Paramecium*) the body of animal is transversely divided into two daughters. In a few flagellates (*Oxythis*) transverse binary fission is seen.

(iv) ***Oblique binary fission.*** Here the division of body is somewhat oblique as in *Ceratium* and *Cochiodinium*.

(v) ***Repeated binary fission.*** In this method the daughter individuals produced by first binary fission fail to separate and

undergo repeated binary fission giving rise to four or more individuals e.g. Colonial protozoa include *Dinobryon*, *Polykrikos* etc.

(vi) ***Encysted binary fission.*** During unfavourable condition this mode of reproduction occurs. The animal secretes a cyst around itself and divides by binary fission as in *Amoeba, Colpoda, Tillina* etc.

2. **Multiple Fission.** In multiple fission the nucleus divides many times either by mitosis or by fragmentation into many nuclei without the division of cytoplasm. The daughter nuclei arrange themselves along the periphery of the animal and are surrounded by a bit of cytoplasm forming daughter individuals. Their number varies in different animals and may reach thousands in some. They become free by the rupture of parental body and lead their independent lives. Multiple fission is very common in Radiolaria, Foraminifera, Sporzoa and Mastigophora.

The multiple fission occurs at different phases in life-cycle of different individuals and are named accordingly. The multiple fission can be divided into following three groups:

(i) ***Agamogony*** or ***Schizogony.*** Asexual process not related to the sexual phenomenon. Product of schizogony grows into trophozoite. e.g. *Plasmodium.*

(ii) ***Gamogony.*** Multiple fission yields gametes which take part in sexual reproduction e.g. *Monocystis.*

(iii) ***Sporogony.*** The multiple fission in the zygote is known as sporogony. The offspirings are known as spores which are infective stage.

Fig. 13.1 Schizogony in *Ovivorra.*

On the basis of presence of characteristic organelles, the individuals formed are variously named:

(a) Pseudopodiospores. The spores which posses pseudopodia are called pseudopodiospores.

(b) Flagellospores. Those protozoa in which flagella are formed as a result of sporogony are called flagellospores.

(c) Swarm spores. When the individuals, formed from the multiple fission, are motile, they are called swarm spores.

Fig. 13.2 Plasmotomy in *Pelomyxa.*

3. **Plasmotomy.** It is common in multinucleate protozoa such as *Opalina, Pelomyxa* and *Actinosphaerium.* Here the cytoplasm is divided into several pieces, each containing several nuclei. Here the nuclear division does not occurs. Each of the daughter regains the normal number of nuclei by the division of parental nuclei.

4. **Budding.** Here the nucleus divides and cytoplasm emerges out in the form of one or more projections each have a daughter nucleus, these projections detache and develop into individuals. The projections are called *buds.* The process of budding is not common in protozoa. It occurs regularly in Suctoria. According to the number of buds there are two types of budding:

(i) ***Single gemmation or Monotomic budding.*** When only one bud is formed at a time e.g. *Vorticella.*

(ii) ***Multiple gemmation.*** When many buds are formed simultaneously e.g. Suctoria.

According to the formation and position of buds, the budding is of two types:

(i) ***Exogenous buds.*** When the buds are formed as outgrowths on the parental body which later pinch off as in many Suctoria, *Noctiluca* etc.

(ii) ***Endogenous buds.*** Here the buds are produced inside the body of parent in special spaces called *brood-chamber* as in some Suctoria, Testacea etc. The apical surface of the parent is invaginated to form the brood pouch which is lined ectoplasm.

II. Sexual Reproduction

Sexual reproduction takes place among Sporozoa, Ciliata and Suctoria. It has been reported from many Foraminifera, Heliozoa, Hypermastigina and Phytomastigina. Two types of sexual reproduction have been distinguished besides some aberrant forms of conjugation are found in the species of *Paramecium.*

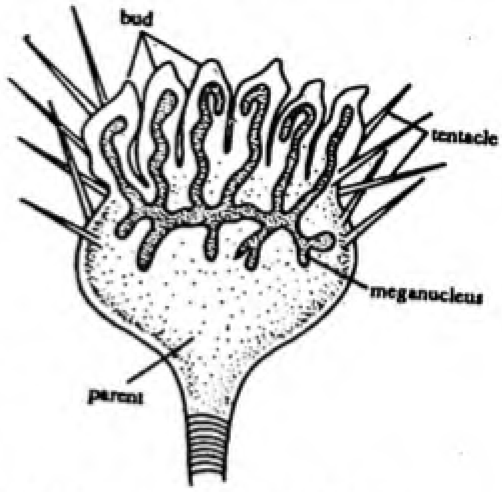


Fig. 13.3 Exgenous budding in *Ephaleta*

1. Syngamy

2. Conjugation

1. **Syngamy.** It involves the complete fusion of two gametes by which the zygote is formed. Depending upon the degree of differentiation of gametes syngamy is distinguished into following types;

   (i) ***Hologamy***. It is the fusion of two mature organisms which do not produce gametes, but behave as gametes as in *Trichonympha* and in certain rhizopods.

   (ii) ***Paedogamy***. If the fusion of gametes takes place in young individuals it is called paedogamy. e.g. *Actinophrys.*

   (iii) ***Isogamy***. When the gametes are similar in size and form. They are called isogametes and their union is isogamy. It is common in Forminifera, Gregarinida and Phytomonadina.

   (iv) ***Anisogamy***. The gemetes, fusing in this type, differ from each other in shape, size and behaviour. The gemetes are called anisogametes and their fusion is known as isogamy. The smaller, motile and active gametes are the *microgametes* or *male gametes* and the bigger, non-motile and passive gametes are *female gametes* or *macrogametes.* Anisogamy is more common in *Plasmodium, Eimeria, Volvex, Protopalina* etc.

   (v) ***Microgamy***. In some Foraminifera and *Arcella,* two types of microgametes are formed. When the microgametes of one animal fuse with the microgametes of other, the fusion is called microgamy.

   (vi) ***Macrogamy***. When union occurs between the macrogametes of the same species e.g. *Actinophrys.*

   (vii) ***Merogamy***. Here the gametes are formed by the division of the normal individuals. These gametes are of different shape and structure from the parents.

   (viii) ***Exogamy***. It takes place between the offspring of different parents.

   (ix) ***Autogamy***. Fusion of gametes derived from the same parent cells. e.g. *Actinosphaerium.*

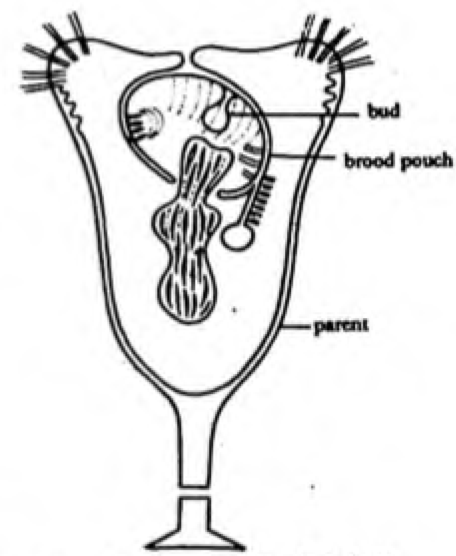


Fig. 13.4 Endogenous budding in *Actineta*

Significance of Syngamy. In syngamy the fusion of the two nuclei takes place results in synkaryon. Syngamy has following effects:

(i) Two different types of hereditary characters come together.

(ii) Variations are developed in the individuals.

(iii) It renews vigour which is lost due to repeated binary fission.

(iv) The fusion of nuclei initiates the development of egg.

2. Conjugation. *Conjugation* is a temporary pairing of two individuals, the *conjugants*, that separate after mutual exchange of male pronuclei. Conjugation is characteristic of Ciliates e.g. *Paramecium*, *Vorticella* etc. In *Paramecium* the conjugants are separated but in *Vorticella* there are two conjugants one large macroconjugants and other microconjugant which is smaller. The microconjugant dies after conjugation. (For detail see chapter *Paramecium*.

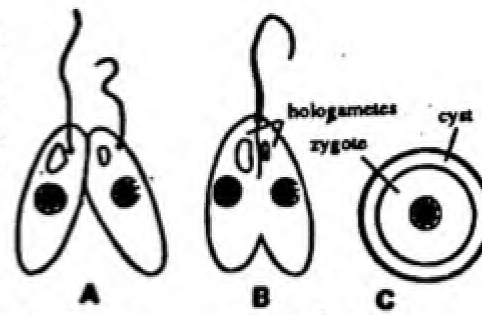


Fig. 13.5 Hologomy in *Copromonas*.

Significance of Conjugation. The significance of conjugation has been:-

(i) It is a process of rejuvination and reorganization by which the vitality of race is restored.

(ii) New nuclear combinations and new hereditary combinations.

(iii) The metabolic activities of the animal are increased by the formation of a new nucleus in place of the old one.

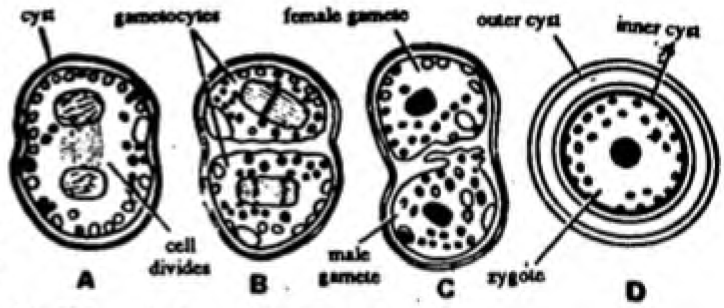


Fig. 13.6 Paedogamy in *Actinophrys*.

Aberrant Behaviour in Reproduction

1. ***Automixis*** Here the fusing nuclei are derived from the same micro-nuclei of the same individual. This can be:

(a) *Autogamy.* In this the fusion of two pronuclei of the same individuals. It corresponding to self-fertilization in higher animals. e.g. *Paramecium aurelia.*

(b) *Paedogamy.* It is the fusion of two young daughters produced by the same parent, e.g. *Actinophrys.*

2. ***Endomixis.*** It is a type of nuclear organization with a single individual of *P. aurelia* without nuclear division and nuclear fusion.

3. ***Hemixis.*** It is a process of recognization of macronucleus without any change in the micronucleus. In certain species of *Paramecium* small fragments of macronucleus fall apart and are absorbed in the cytoplasm. The remaining part of macronucleus behaves normally.

4. ***Regeneration.*** The body protoplasm possess the power of regeneration of the lost part. Any small part of cytoplasm (ectoplasm and endoplasm) with a fragment of nucleus can regenerate into a new individuals.

5. ***Parathenogenesis.*** In certain animals like *Actinophrys, Chlamydomonas* etc. The gametes fail to unit so as to form synkaryon so that the gametes develop into adult without fertilization. Such a development is called parthengensis.

6. ***Plasmogamy.*** In some rhizopods it has seen observed that two individuals unite with each other and their cytoplasm become one but their nuclei remain separate. After sometime they separate from each other without any change. This process is called plasmogamy.

14

ECONOMIC IMPORTANCE OF PROTOZOA

The protozoa are acellular, microscopic organisms found everywhere, in water, soil, on the body of plants and animals. Although they are minute and apparently insignificant, but they are ofconsiderable economic value to the mankind. The activities of these organisms can be divided the following two heads:

1. Beneficial

2. Harmful

BENEFICIAL PROTOZOA

The protozoa are useful in the following ways:

1. *Food.* Protozoa provide food for insect larvae, crustaceans and worms, which are taken by large animals like fishes, lobsters, clams, and crabs, which are eaten by man. Thus they form sources of food supply to man both directly and indirectly.
2. *Symbiotic Protozoa.* Certain protozoa like *Trichonympha* and *Colonymphya* etc. live in the gut of termite which help in the digestion of cellulose. The digested cellulose is utilized by the host.
3. *Insect Control.* Several protozoa control harmful insects by persisting their bodies.
4. *Helpful in Sanitation.* A large number of protozoa living in polluted water feed upon waste organic matters and thus purify it. Many protozoa feed upon bacteria and play important role in the sanitary betterment and keeping water safe for drinking (*Kudo*, 1947).
5. *Industry.* The skeletal deposits of marine protozoa (Foraminifera and Radiolaria) form oceanic ooze at the sea-bottom. About 30% of oceanic bed is covered with the *Globigerina* ooze. These skeletal deposits are put to many uses. Some are employed as filtering agents, others are made into chalk and still others are used for abrasives.
6. *Building material.* The skeletal deposits in due course of time change into the limestone rocks. Limestone is provided by the *Globigerina* ooze, such as that of cliffs of Dover, which have played an important role in the defence of England. *Camerina* (formally known as *Nummulites*, are the largest protozoa, which form limestone. The pyramids of Egypt are made largely of this Nummulitic lime-stone. Thus, limestore-beds are used as building material.
7. *Oil Exploration.* Petroleum is of organic origin. The skeletal deposit of Forminifera and Radiolaria are often found in association with oil deposits. In this manner they help in the exact location of oil.
8. *Scientific Study.* Many protozoa are used in biological and medical researches. A Holotricha, *Tetrachymena geleii* is used in nutritional research. The effects of various foods and poisons have been investigated on this protozoan.

HARMFUL PROTOZOA

The protozoa are harmful in following ways:

1. *Pollution of water.* Drinking water in natural condition is made unpalatable by the reproduction of some free-living protozoa in it. For example, *Uroglenopsis* brings fleshy odour like that of cod-liver oil. *Peridinium* emits smell resembling that of clam-shells.

2. ***Destruction of animals of food value*** Biolumeniscent dinoflagellates like *Noctiluca* and *Gonyaulax*, when become abundant, are responsible for turning the ocean red. The water becomes foul and cause toxic reaction to molluscs like clam, oysters and mussels and they become unfit for eating by human beings.

3. ***Destruction of Wooden articles.*** Some flagellates like *Trichonympha* and *Colonympha* live in the gut of termites and help in the process of cellulose digestion. In the absence of these flagellates the termites will die or change their diet. Thus such protozoa indirectly help in destruction of wooden articles and books.

4. ***Reduction in fertility of soil.*** It has been observed that about 200 - 300 species of protozoa are present in soil. These protozoa feed on nitrogen-fixing bacteria thus reduce the fertility of soil.

5. ***Parasitic Protozoa.*** Parasitism is an association of two organisms in which one organism lives at the expense of the other giving nothing in return. The first animal is called parasite and other the host. Parasitism is a specialized mode of life and various level of it are found in protozoa. There are two type of parasites on the basis of their survival: *Facultative parasites* are those that can live for various lengths of time without the host. The *obligatory parasites* are those which cannot survive when separated from their host.

Depending upon the nature and degree of intimacy and the placement of the parasites on their hosts. There are two types of parasitics:

(A) *Ectoparasites.* When the parasite lives on the external surface of the host, it is called ectoparasite. A few species like *Hydramoeba hydroxena* (found on epidesmis of *Hydra*); *Costa necatrix* found in the epidermal cells of fishes, and *Ichthyophthirius multifilis*, inhibiting in the skin of fishes. They feed on the liquified host cells causing various degrees of cellular necrosis. These parasites are transferred directly from host to host.

(B) *Endoparasites.* When the parasite lives inside the body of the host such parasite is called endoparasite. Following types of endoparasites are there depending upon their location:

1. *Coelozoic.* When the parasite lives in the alimentary canal or cavities of host body. For example *Entamoeba histolytica, Giardia lamblia, Balantidium coli* etc.

2. *Histozoic.* Which occupies space between the host cells. For example young trophozoie of *Monocystis* lives in sperm morula of earthworm. *Trypanosoma gambiense* lives in the blood plasma of verebrates.

3. *Cytozoic.* These live inside the host's cell. For examples *Plasmodium* and *Babesia* in the blood cells of hosts. *Sarcocystis* lives in the striped muscles of host.

Effects of Parasitism of the parasite.

Parasitic protozoa are usually simplified in their structure. They do not possess any elaborate organelles, except the ciliate parasite. The endoparasites show maximum structural simplicity. They lack contractile vacuoles, locomotory and ingestory organelles. However, coelozoic forms like *Trichomonas, Giardia* and *Balantidium* possess locomotory and ingestory organelles. Surplus food is stored as glycogen, volutin granules and chromatoid bodies. Many parasites are aerobic as well as anaerobic depending on the availability of oxygen. Some protozoa like *Gregarina* develops the organelles of attachment. Occurrence of complicated life-cycle often involving cyst-formation and repid multiplecation by merogony and schizogony.

Effects on hosts.

The parasites are of two types non-pathogenic and pathogenic. The non-pathogenic parasites have no noticeable ill-effects on the host. For example *Entamoeba coil, Trichomonas hominis, Endolimax nana* etc. The pathogenic parasites are those which cause ill-effects or diseases to the hosts.

Transmission of parasite to other host and its infection. The infection of new host takes place in two steps first the exit of parasite from the first host, and second the transmission in the second host. Following ways are there in which the parasitic protozoa reach new hosts:

1. ***Active migration.*** This occurs in epizoic parasites of aquatic hosts e.g. *Ichthyophthirius* which actively comes out of the host i.e. fish and infects the other host.

2. ***Direct transfer***. This type of infection takes place on coming in contact of the other host e.g. ***Trichomonas vaginalis*** etc.
3. ***Accidental infection***. In this method the new host is infected accidently swallowing of the parasite in the encysted condition along with food and water e.g. *Coccidia, Entamoeba histolytica* etc.
4. ***Infection by intermediate host***. This takes place in blood-parasites like ***Plasmodium*** and ***Trypanosoma*** in which a vector transmits the parasite through blood sucking (like female *Anopheles* mosquito, tsetse fly *Glossina*). The developmental stages may or may not be found in the vector.
5. ***Congential transfer***. The germinative infection, taking place at or before birth, may occur in several ways as placental transfer takes place in case of *Plasmodium* in man, ovarian transfer as takes place in *Nosema* in silkworm etc.

Pathogenic Protozoa

The disease causing protozoa are called pathogenic protozoa. Such protozoa are met within all the classes of this phylum. In man alone, more than 25 types of parasitic protozoa are found. Depending upon the location inside the host body, these are divided into various groups. These are:

1. **Parasites of mouth.**
   (i) ***Entamoeba gingivalis***. A sarcodine lives in the tartar of teeth and pockets of gums. They probably aggravate pyorrhoea in man. They are also found in dogs and cats. The human infection is caused by kissing.
   (ii) ***Trichomonas tenax***. A flagellate also lives in pus pockets formed between teeth and gums. It causes *pyorrhoea*. It is transmitted during kissing.
   (iii) ***Leishmania braziliensis***. A flagellate lives in the oro-nasal mucous membrane. It causes *espundia*. The infection is transmitted to man by the bite of sand-fly.

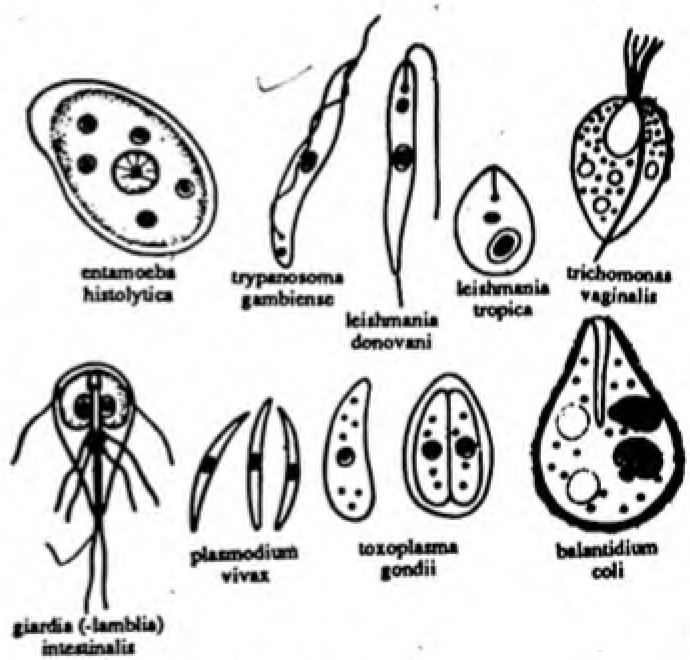


Fig. 14.1 Various Pathogen *Protozoans*.

2. **Parasites of Digestive Tract.**
   (i) ***Entamoeba histolytica***. It lives in the colon of man, sometimes in dogs and cats. It causes *amoebic dysentery*. It may reach liver, spleen, lungs and liver and causes *amoebic abscesses*. Infection takes place by swallowing of cysts.
   (ii) ***Trichomonas hominis***. It lives in large intestine of man, monkeys, cats and dogs. It causes *diarrhoea* and *dysentery*. It is transmitted through infective cysts.
   (iii) ***Chilomonas***. It lives in large intestine of man and causes *diarrhoea* and allied troubles. Transmission is by means of infective cysts.
   (iv) ***Giardia intestinalis***. It lives in the large intestine of man causing *diarrhoea*. Transmission takes place by tetranucleated cysts with contaminated food and water.
   (v) ***Isopora hominis***. It lives in the large intestine. Some other species occur in dogs and cats. They cause *diarrhoea* and abdominal discomforts. Infection occurs by oocysts through contamination.
   (vi) ***Sarocystis***. It occurs in the muscles of oesophagus of sheep causing weakness of muscles. Transmission by cysts.
   (vii) ***Nosema apis***. It occurs in the intestine and Malpighian tibules of honey bee causing *Nosemia*.

(viii) ***Balantidium coli.*** It lives in the colon of man causing chronic ciliary dysentery. Transmission is by infective cysts.

(ix) ***Eimeria.*** It is found in the digestive tract of sheep, birds and cattle. It causes *diarrhoea* to haemorrhage. Transmission by oocysts.

(x) ***Trichomonas gallinae.*** It is found in the epithelial lining of oesophagus and crops of fowl, pigeons and turkeys. It causes necrotic modules. Transmission through droppings.

(xi) ***Histomonas meleagridis.*** It lives in the caecum and liver of turkeys and fowls causing black-head disease. Transmission by ingesting contaminated eggs of caecal worm.

3. Parasites of Blood and Lymph.

(i) ***Trypanosoma sps.*** A number of species of *Trypanosoma* are parasitic in the blood of man and other vertebrates. These are:

(a) ***Trypanosoma. gambiense.*** It occurs in the blood of man causing African sleeping sickness. It is transmitted through the bite of tsetse fly, *Glossina palpalis.*

(b) ***T. rhodesiense.*** In man it causes Rhodesian sleeping sickness. It is transmitted through the bite of tsetse fly, *Glossina morsitans.*

(c) ***T. cruzi.*** In early stage it is found in the muscles, heart, brain, spinal cord and in later stages in the blood. It causes *Chaga's disease* in South and Central Africa. Infection transmitted by the bite of bug, *Triatoma magista.*

(d) ***T. brucei.*** It causes *nagana disease* in domesticated cattles and it is transmitted by *Glossina morsitans.*

(e) ***T. evensi.*** It occurs in the blood of horses, dogs, camels etc. It causes *surra disease.* It is transmitted by *Tabanus fly.*

(f) ***T. equiperdum.*** It is found in the blood and germinal epithelium of horses, dogs and donkeys. It causes *dourine* disease in horse. The disease is transmitted during copulation.

(ii) ***Leishmania sps.*** It is a parasite of man and other animals. A number of species are there:

(a) ***Leishmania donovani.*** It is found in the endothelial cells of blood and lymph capillaries and leucocytes in the spleen, liver, bone marrow and lymph gland causing *visceral leishmaniasis* or *kala-azar.* Infection occurs by the bite of sand-fly, *Phlebotomus.*

(b) ***L. tropica.*** It occurs in the endothelial cells of dermal tissues causing *Oriental sore* or *cutoneous leishmaniasis* in man. Infection occurs by the sand-fly.

(c) ***L. infentum.*** It occurs in the spleen of children. It causes enlargement of spleen. Transmission by the bite of sand-fly.

(iii) ***Plasmodium sps.*** A number of species of *Plasmodium* occur as intracellular parasites in red blood corpuscles of man and birds. The *Anopheles* female is the vector. These are.

(a) ***Plasmodium vivex.*** It causes *benign tertian malaria.*

(b) ***P. ovale.*** It also causes *benign* tertian malaria.

(c) ***P. falciparum.*** It causes *malignant tertian.*

(d) ***P. malariae.*** It causes *quartan* fever.

(e) ***P. praecox.*** It causes malaria in birds.

(f) ***P. gallinaceum.*** It causes malaria in chickens and pheasants.

(iv) ***Babesia sps.*** Three species of *Babesia* found in cattles, dogs and horses, these are:

5

(a) ***Babesia bigemina.*** It occurs in R.B.Cs. of cattles causing *Texas* or *Red water fever*. It is transmitted by the bite of tick *Boophilus.*

(b) ***B. equi.*** It occurs in the R.B.Cs. of horses causing *jaundice* and sometimes paralysis of hind-limbs. Transmission through the ticks.

(c) ***B. canis.*** It occurs in the R.B.Cs. of dogs causing *malignant jaundice* fever. Transmission by ticks.

(v) ***Haemoproteus.*** It is found in the R.B.Cs. and endothelial cells of blood vessels in birds.

(4) Parasites of Urinogenital tract.

(i) ***Trichomonas vaginalis.*** It is found in the vagina of female causing *vaginitis* (annoying itch and abnormal discharge) and in man it is found in urethra. Transmission is direct through inter-course.

(ii) ***Trichomonas foetus.*** It occurs in the urinogenital system of sheep, horse and cattles. It causes uterine and penial disorders. Transmission is direct through intercourse.

(iii) ***Eimeria truncata.*** It occurs in the kidneys of goose and often causes death of the host.

15

GENERAL CHARACTERS & CLASSIFICATION OF PORIFERA

Sponges which constitute Phylum Porifera, are the most primitive of the multicellular animals. Neither true tissues nor organs are present, and the cells display a considerable degree of independence. All the members of the phylum are sessile and exhibit little detectable movement. This combination of characteristic convinced *Aristotle, Pliny,* and other ancient naturalists that sponges were plants. In fact it was not until 1765, when internal water currents were first observed by *Ellis*, that the animal nature of sponges became clearly established. As a result, *Linnaeus, Lamarck* and *Cuvier* placed the sponges under Zoophytes or Polypes in their systems, regarding them as allied to anthozoan coelenterates, and many investigators sought to find in sponges the polyps they thought must be there. *de Blaiville* (1816) recognized the lack of affinities of sponges with coelenterates and separated them into a group spongiaria allied to Protozoa, but this idea gained little attention, and, through much of the 19th century, sponges were placed with coelenterates, usually under the name Coelenterata or Coelentera or Radiata. Morphology and physiology of sponges were first understood by *Robert E. Grant* (1825), who coined the term Porifera (*L. porous* = pore; *ferro* = to bear). *Huxley* (1875) and *sollas* (1884) proposed the complete separation of sponges from other Metazoa on the ground of many peculiarities, but this view did not find its present general acceptance until about the beginning of 20th century. Sponges are now recognized as constituting a separated isolated branch of the Metazoa, named Parazoa, after *Sollas.*

General Characters

1. All sponges are aquatic, mostly marine but a few are fresh-water.
2. They are multicellular organisms with cellular grade of body organisation without forming tissues or organs.
3. They are sessile, solitary or colonial.
4. They have asymmetrical or radially symmetrical bodies.
5. The body is cylindrical, tubular or vase-like.
6. The body wall is *diploblastic* with outer dermal epithelium and inner gastral epithelium with a gelatinous non-cellular *mesenchyme* in between.
7. The body surface bears numerous minute pores i.e., *ostia* for the ingression of water.
8. They possess peculiar *canal system* through which water current flows drawing food and oxygen inside the body and carrying away excretory and reproductive products.
9. Internal skeleton is present in the mesenchyme in the form of calcareous or siliceous *spicules* or of proteinous *spongin fibres.*
10. Digestion is entirely intracellular.
11. Nervous and sensory cells are lacking.
12. All sponges possess great power of regeneration.
13. They are mostly bisexual but asexual forms also exist.
14. Reproduction takes place both by asexual and sexual methods.
15. Asexual reproduction takes place by budding, fission or *gemmule* formation and sexual reproduction by *sperms* and *ova.*
16. Fertilization is internal and at the same time it is cross fertilization.

17. Cleavage is holoblastic and development is indirect followed by a free swimming ciliated larva, the *amphiblastula* or *parenchymula.*

CLASSIFICATION

The classification of sponges presented great difficulty, and no one scheme has been unanimously accepted by specialists on sponges. The classification is based on the type of skeleton, and this serves to mark off rather sharply two groups of sponges, the calcareous and the glass sponges. The remaining silicons and horny sponges are, however, less clearly delimited, and they are variously subdivided by different workers. The classification here adopted is that given by *Topsent, Wilson* and *de Laubenfels.*

Phylum Porifera is divided into three classes :

Class-1. Calcarea

The members of this class possess their skeleton composed of separate calcareous spicules made of calcium carbonate (*L., Caleis* = lime; Gr., *sponges* = sponge).

1. Members of this class are smaller in size, extending upto 15 cm in length; may be solitary or colonial. All are marine.
2. Shape of body usually cylindrical or vase-like.
3. Osculum is narrow, terminal and fringed with spicules.
4. The colour of the body is white or dull-brown.
5. Skeleton consists of spicules which may be *monaxon, triradiate* or *tetraradiate.*
6. Collar cells or *choanocytes* are comparatively large.
7. The canal system is ascon, sycon or leucon type.

Order - (i) Homocoela

1. Body is small, cylindrical and thin walled without any foldings.
2. Canal system ascon type.
3. Spongocoel is lined throughout by choanocytes.

   Examples : *Leucosolenia, Clathrina.*

Order - (ii) Heterocoela

1. Body is comparatively bigger, vase-like, thick walled with internal foldings.
2. Canal system sycon or leucon type.
3. Choanocytes are restricted to the flagellated chambers.
4. Spongocoel is lined by dermal epithelium.

   Examples : *Scypha* or *Sycon, Grantia.*

Class 2. Hexactinellida or Triaxonida

The members of the class are called glass-sponges having *triaxon* or *hexactinal* spicules made up of silica.

1. Members of this class are of moderate size, extending up to 1 meter in length and are usually solitary.
2. The body shape is usually cylindrical, cup-shaped or funnel-shaped.
3. The osuclum is wide and usually covered over by a siliceous sieve plate.
4. The skeleton consists of *triaxon* or *hexactinal* siliceous spicules, often fused resembling spun glass.

5. Dermal epithelium is wanting.
6. The canal system is simple rhagon type.
7. The choanocyte cells are restricted to finger-like flagellated chambers.
8. They are exclusively marine and occur chiefly in tropical deep sea water.

Class Hexactinellida is divided into two orders :

Order (i) - Hexasterophora

1. The beautiful glass-like body is cylindrical, very light and attached to the substratum directly.
2. The spicules are *hexasters* having star-like appearance.
3. The flagellated chambers are radially and regularly arranged.

Example : *Euplectella* (Venus's flower basket).

Order (ii) - Amphidiscophora

1. The body is usually rounded or oval and attached to the substratum by root tufts.
2. The spicules are *amphidiscs* having a convex disc, bearing a crown of backwardly directed marginal teeth at both ends.
3. The flagellated chambers are irregularly arranged.

Example : *Hyalonema* (Glass rope sponge).

Class 3. Demospongiae

This class comprises diverse and complicated sponges with skeleton of siliceous spicules or spongin fibres or a combination of both or totally absent. (Gr., *demos* = frame; *spongos* = sponge).

1. Members of this class are highly organised, varying from small to large size and may be solitary or colonial.
2. The body shape is variable being rounded, oval, cup-like or funnel-like.
3. The skeleton is made up of silicious spicules or spongin fibres or both. The spicules are monaxon or tetraxon.
4. Canal system is complicated and leucon type.
5. Choanocytes are restricted to small flagellated chambers.
6. They are mostly marine but few sponges are fresh water.

Class Demospongiae is divided into three sub-classes :

Subclass-I. Tetractinellida

1. Body is rounded or flatenned.
2. Silicious spicules, if present are tetraxon, or absent.
3. Spongin fibres are absent.

Order (i) Myxospongia

1. Spicules are absent
2. Body surface is velvet-like

Example : *Oscarella*.

Order (ii) Carnosa

1. Homogenous leuconoid structure.
2. Spicules are of equal-size.

Examples : *Chondrilla, Plakina, Halina.*

Order (iii) Choristida

1. Body form is usually elaborate:
2. Both small (microscleres) and large (megascleres) spicules are present.

Example : *Geodia, Ancoria.*

Subclass-II, Monaxonida

1. Body form variable, occurring in shallow and deep water.
2. The skeleton consists of monaxon spicules distinguished into megascleres only.
3. Spongin fibres may or may not be present.

Sub-class Monaxonida is divided into four orders :

Order (i) Hadromerina

(i) Megascleres are mostly *tylostyles* i.e. the broad end is knobbed.
(ii) Microscleres are usually absent and if present, are star-like.
(iii) Spongin fibres are absent.

Examples : *Cliona* (Boring sponge), *Suberites, Poterion.*

Order (ii) Halichondrina

(i) Megascleres are always of more than one kind.
(ii) Microscleres are usually absent.
(iii) Spongin fibres are present but they are very scanty.

Example : *Halichondria.*

Order (iii) - Poecilosclerina

1. Megascleres are usually of two or more kinds and united by spongin fibres into a regular network.
2. Microscleres may be curved, bow-shaped or C-shaped.

Examples : *Myxilla, Microciona.*

Order (iv) - Haploscerina

(i) Megascleres are always diactinal and pointed at both ends.
(ii) Microsclers may or may not be present.
(iii) Spongin fibres are usually present.

Examples : *Chalina, Spongilla* (fresh-water).

Sub-Class 3, Keratosa

(i) The body form is usually rounded and massive with a leathery surface and dark colour, occurring generally in warm shallow water.

(ii) The skeleton is exclusively composed of spongin fibres.

(iii) The spicules are totally absent.

Examples : *Euspongia* (Bath sponge), *Hippospongia* (Horse sponge).

CLATHRINA

Phylum	-	Porifera
Class	-	Calcarea
Order	-	Homocoela
Genus	-	*Clathrina*

1. It is a simple, marine sponge attached to the hard substratum.
2. It is sedentary sponge with a free end containing *osculum*.
3. The surface is perforated by minute apertures called *ostia*, through which the water enters the body. Canal system asconoid type.
4. Skeleton consists of calcareous spicules which are triradiate with equal rays.
5. Choanocytes lines the spongocoel.
6. Dermal membrane or cortex is lacking.

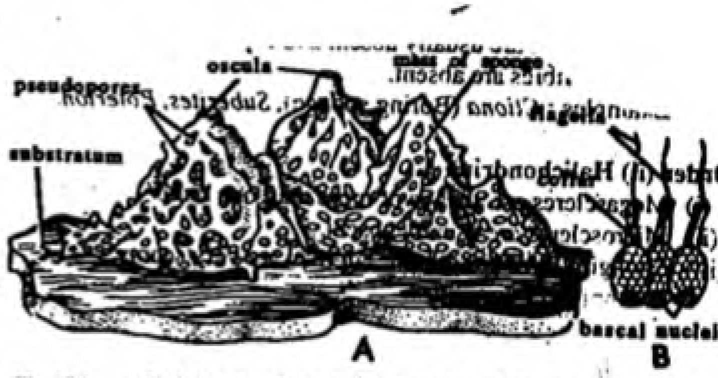


Fig. 15.1 *Clathrina* A—Colony of *Clathrina clathrus*. B—Choanocytes of *Clathrina coriacea*.

7. Development includes a parenchymula larva and the so called olynthus stage.

GRANTIA

Phylum	-	Porifera
Class	-	Calcarea
Order	-	Heterocoela
Genus	-	*Grantia*

1. It is a small, solitary or colonial, marine sponge.
2. It is found in the Gulf of St. Lawrence.
3. The body is complex vase-like.
4. Each cylinder bulges in the centre and opens to the exterior by an osculum.
5. The osculum is encircled by a fringe of large giant monaxon spicules forming oscular fringe.
6. The body surface is covered by the dermal membrane forming a cortex of varying thickness having special cortical spicules. The spicules are tangential radiate.
7. Body wall is composed of outer dermal epidermis, middle mesenchyme and inner flatenned epithelium lining the spongocoel.

Fig. 15.2 *Granitia*

8. Canal system is sycnoid.
9. Choanocytes are restricted to the radial canal, and the flagella arise directly from nuclei.
10. Bisexual. Reproduction by asexual and sexual methods. Asexual reproduction by budding and regeneration. Sexual by gametes. Larva is an amphiblstula.

LEUCILA

The classification is the same as that of *Grantia.*

1. It is a small, marine and solitary sponge.
2. It is found in Europe and U.S.A.
3. The body is somewhat globose in shape as the anterior region is narrow and the posterior region is broad.
4. The osculum is situated at the anterior most end and is surrounded by oscular fringe of monaxon specules.
5. The spngocoel is narrow while the body wall is quite thick.
6. Canal system is primitive leuconoid type. Each radial canal is subdivided into elongated flagellated chambers grouped around a common excurrent canal.
7. The skeleton is of inarticulate type.

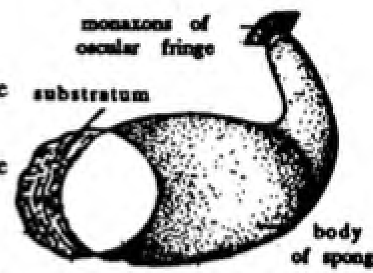


Fig. 15.3 *Leucila*

LEUCANDRA

The systematic position is the same as the of *Grantia.*

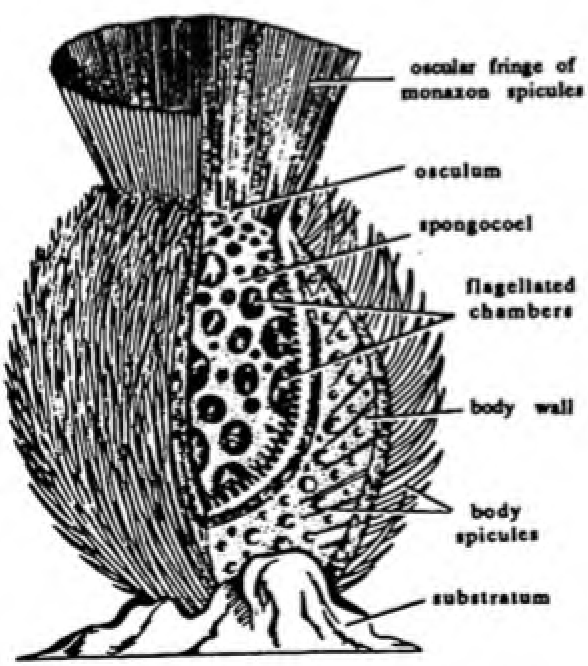


Fig. 15.4 *Leucendra*

1. It is a small, marine and solitary sponge.

2. Body is globose in shape.
3. Body wall is thick. Osculum is situated at the anterior end and is surrounded by oscular fringe of monaxon spicules.
4. Dermal skeleton is formed of tangentially arranged triradiate spicules which may sometimes develop an apical ray.
5. The flagellated chambers are small and spheroidal.

OSCARELLA

Phylum	-	Porifera
Class	-	Demospongia
Subclass	-	Tetractinellida
Order	-	Myxospongia
Genus	-	*Oscarella*

1. It is found in shallow water forming encrustation over the rocks and submerged objects.
2. It occurs in British water.
3. It is a bright coloured small sponge whose upper surface is lobulated.
4. The canal system is leuconoid type.
5. The lobules are covered with thin dermal layer. Each lobule contains excurrent canal surrounded by flagellated chambers and the depression between the lobules house the incurrent canal.
6. Skeleton is absent *i.e.* the spicules are completely absent.

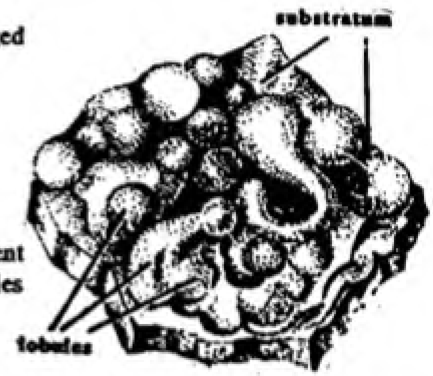


Fig. 15.5 *Oscarella*

CHONDRILLA

Phylum	-	Porifera
Class	-	Demospongia
Subclass	-	Tetractinellida
Order	-	Carnosa
Genus	-	*Chondrilla*

1. It is marine sponge found in British water and U.S.A.
2. The entire body looks like a rounded mass hence commonly called *chicken-liver* sponge.
3. The body remains attached to rocks etc.
4. Free surface contains few osculae.
5. Body surface is smooth, but mesogloea is thick and stony due to spherasters.
6. Canal system is leuconoid type.
7. The spherasters found in cortex between the cones and are well developed while other spicules are absent.

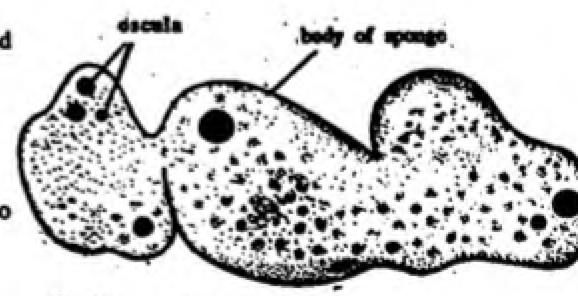


Fig. 15.6 *Chondrilla*

CLIONA

Phylum	-	Porifera
Class	-	Demospongia
Sub class	-	Monaxonida

Order	-	Hadromeria
Genus	-	*Cliona*

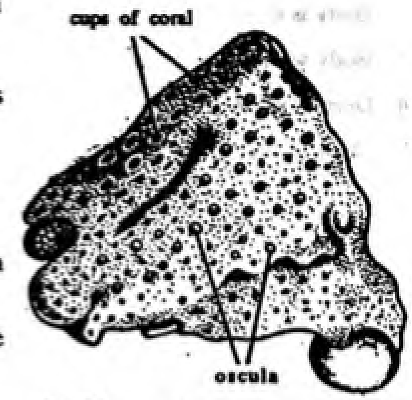


Fig. 15.7 *Cliona*

1. It forms low encrustation on rocks, mollsc shells, coral skeleton and other calcareous objects.
2. It is cosmopolitan in distribution.
3. It is commonly called 'Boring sponge' or 'Sulphur sponge'.
4. It is light yellow in colour but may be green or purple, and forms a mass upto 20 cm in diameter.
5. It enters the interior of above animals and lives permanently there, forming extensive burrows and tunnels.
6. Each tunnel has a raised osculum.
7. Monaxon spicules form the skeleton of the individual.
8. Sexual reproduction by the formation of gametes. Development indirect through a larval stage. The larva grows into a compact mass.
9. It has sulphurous odour hence commonly called sulphur sponge.

POTERION

The systematic position is the same as that of *Cliona*.

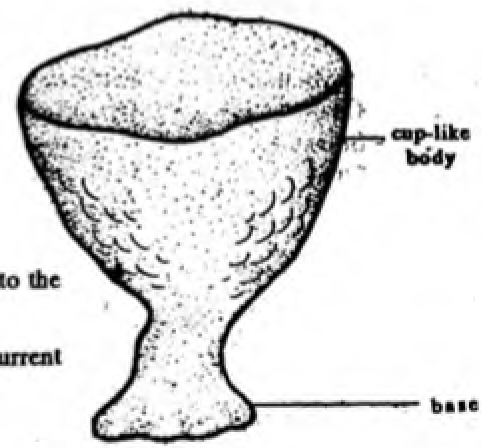


Fig. 15.8 *Poterion*

1. It is a solitary, marine and boring sponge.
2. It is found in the gulf of Mexico and off coasts of North Carolina.
3. It is commonly known as 'Naptune's goblet'.
4. The shape of body is cup-like with a base. The body remains fixed to the substratum by base.
5. The incurrent apertures are present on the outer surface while excurrent apertures on the inner surface.
6. The skeleton is formed of tylostyle (monaxon) spicules.
7. Osculum at the anterior end is very large.
8. It is supposed to be one of the largest sponges, measuring 1-2 metres in bight.

TETHYA

The systematic position is the same as that of *Cliona*.

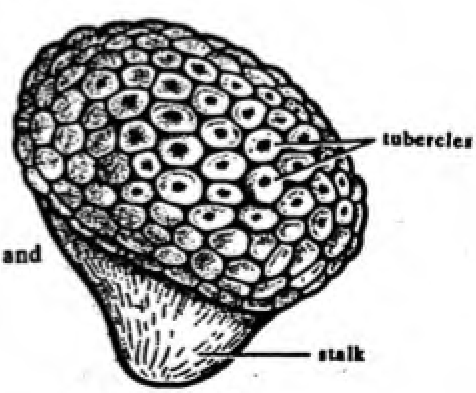


Fig. 15.9 *Tethya*

1. It is a marine sponge inhibiting deep seas.
2. It is a rounded sponge.
3. Body surface tuberculate with radiating bundles of monaxon spicules and several exasters.
4. The styles have indistinct tylote ends.
5. Spongin fibres are absent.

HALICHONDRIA

Phylum	-	Porifera
Class	-	Demospongia
Subclass	-	Monaxonida
Order	-	Halichondrina
Genus	-	*Halichondria*

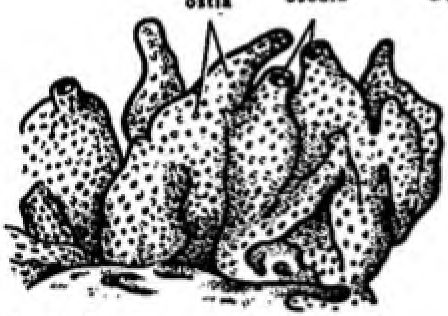


Fig. 15.10 *Helichondria*

1. It is a colonial sponge. It forms low encrustations on rocks in shallow waters.
2. It is cosmopolitan in distribution.
3. It is commonly called the crumb of 'breed sponge'.
4. It is soft and yellowish or green or brown in colour.
5. The surface presents one or more large rounded openings called oscula.

Skeleton consists of oxeas lying withoutany arrangement.

MICROCIONA

Phylum	-	Porifera
Class	-	Demospongia
Subclass	-	Monaxonida
Order	-	Poecilosclerina
Genus	-	*Microciona*

Fig. 15.11 *Microciona*

1. It is a marine, dimorphic, colonial form, found in shallow water as a soft, thin encrusting layer on rocks, shells and calcareous objects with ascending lobes.
2. It is found in long Island Sound and also present in South Carolina to Cape Cod.
3. In deep sea water the colony becomes massive.
4. It is bright red in colour. The animal comprises of several finger-like projections.
5. The spicules are of various forms and united by spongin into a regular network.
6. The animal is used in regeneration and reassociation experiments. This animal has tremendous capacity to reassociate and regenerate.
7. Sexual reproduction by gametes. Development through a free swimming larval stage in early August.

CHALINA

Phylum	-	Porifera
Class	-	Demospongia
Subclass	-	Moxaxonida
Order	-	Haploscerina
Genus	-	*Chalina*

Fig. 15.12 *Chalina*

1. *Chalina* is commonly called *Dead man's finger* found in deep water, orange-brown or red in colour.

2. It is found in Europe, common from Rhode Island to Labrador. North Carolina to Cape Cod.
3. It is much branched and each branch looks like a finger, so also called *mermaid's glove.*
4. Each branch is perforated by numerous openings or oscula.
5. Canal system is leucon type.
6. Monaxon siliceous spicules embedded is spongin fibres constitute the skeleton of this animal.
7. Asexual reproduction by budding and sexual reproduction includes a free-swimming larva.

SPONGILLA

The classification is the same as that of *Chalina.*

1. *Spongilla* is a colonial fresh-water sponge found attached to submerged sticks and plants of ponds, lakes and streams.
2. It is cosmopolitan in its distribution. It is found mainly in Atlantic, European and American waters.
3. Siliceous spicules form the skeleton. The spicules are oxeas, embedded in spongin.
4. Canal system rhagon type.
5. Highly branched colony with numerous oscula.
6. Asexual reproduction by budding and gemmule formation; sexual reproduction also occurs.
7. Gemmules are protected by the amphidisc spicules.

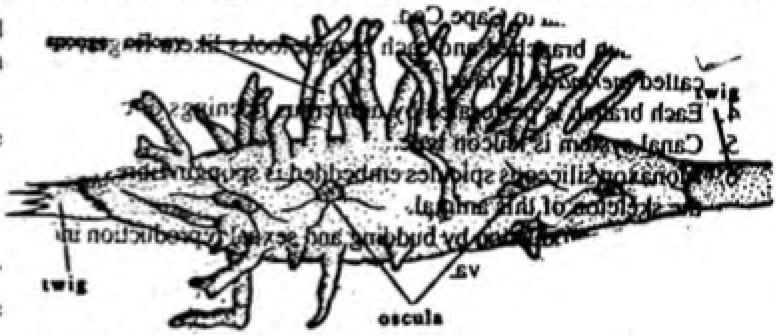


Fig. 15.13 *Spongilla*

EPHYDATIA

The classification is the same as that of *Cliona.*

1. It is a greyish or greenish fresh water sponge found in clear water in rivers, ponds and streams.
2. It is found in Vancouver Island, Eastern and Central States.
3. The body consists of delicate tubes each bears an osculum.
4. Surface is perforated by several large oscula and minute pores the osita.
5. The green colour of animal is due to the symbiont zoochlorellae.
6. Asexual reproduction by gemmules.

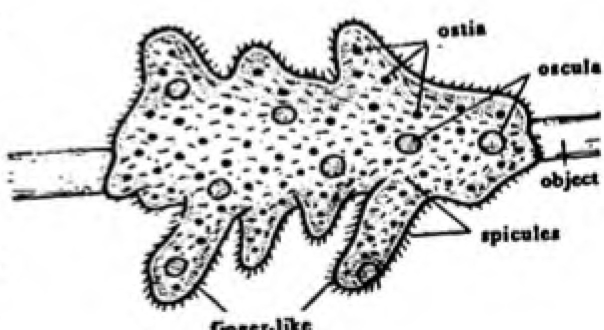


Fig. 15.14 *Ephydatia*

EUSPONGIA

Phylum	-	Porifera
Class	-	Demospongia
Subclass	-	Keratosa
Genus	-	*Euspongia*

1. It is found in shallow water on rocky bottom.

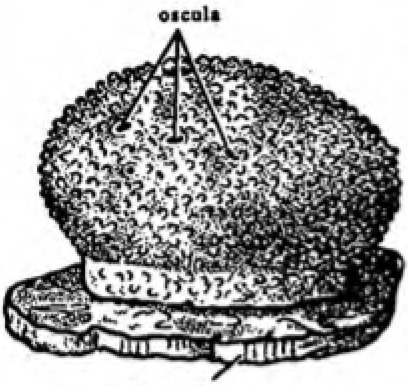


Fig. 15.15 *Euspongia*

2. It has cosmopolitan distribution.
3. It is commonly called 'bath sponge'.
4. It forms a large brownish more or less spherical mass covered by a dark, non-living lathery membrane of spongin.
5. The surface bears small projects, the *conules*, supported by stiff spongin streams.
6. The body surface contains large openings called as oscula, and small openings called inhalant canals.
7. Internally the sponge resembles a liver in both consistency and colour.
8. It is unisexual and males are rare.
9. Skeleton is made of only spongin fibres. Spicules are absent. Many small worms and crustaceams live inside it as commensals.
10. It can live upto 50 years.
11. It is commonly used in bathing, washing automobiles, furnitures, applying face creams etc.

HIPPOSPONGIA

The classification is the same as that of *Euspongia.*

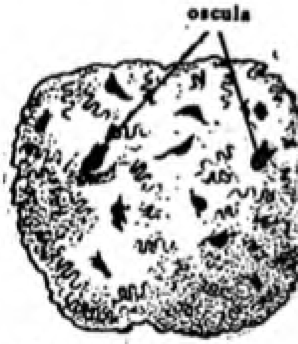


Fig. 15.16 *Hippospongia*

1. It is a horny sponge found 9-16 meters deep.
2. It is found in Mediterranean West Indies and common in Florida.
3. Body is massive and permeated by large, often cavernous canals.
4. Body is covered by a dark and dead membrane provided with numerous flagellated chambers.
5. Body surface is raised at several places bearing oscula. A single sponge is made up of few to many individuals, provided with few to many oscula.
6. Skeleton is made up of spongin only, spicules being absent.
7. It grows very large and may live for 50 years.
8. It harbours several small commensal crustanceans and worms.

Fig. 15.17 *Hircinia*

HIRCINIA

The classification is the same as that of *Euspongia.*

1. It is a marine and sedentary sponge.
2. It has world-wide distribution.
3. It is commonly called horny sponge.
4. It attains a considerable size and rounded massive form. Body surface contains conules.
5. The body colour is due to presence of symbiotic blue-green algae.
6. The canal system is diplodal leucon type.

7. Skeleton consists of spongin fibres only.

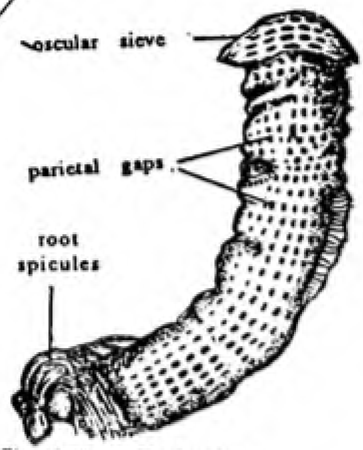


Fig. 15.18 *Euplectella*

EUPLECTELLA

Phylum	-	Porifera
Class	-	Hexactinellida
Order	-	Hexasterophora
Genus	-	*Euplectella*
Species	-	*aspergillum*

1. It is a deep sea form found near Philippine islands and has become curved due to slow water current.
2. It is commonly called *Venus' flower basket* and is a beautiful glass sponge.
3. It is made of six-rayed siliceous spicules which are held together by siliceous cement resulting in a beautiful basket-like structure.
4. The curved upper end of the body is closed by an *oscular sieve.*
5. From the base arise root spicules which are long siliceous threads which fasten the sponge to its unstable slimy substratum.
6. The spongocoel contains a pair of crustacea (*Spongicola*) which had commensal life throughout their life. For this reason *Euplectella* is a beautiful presentation for newly married couple in some countries.

HYALONEMA

Phylum	-	Porifera
Class	-	Hexactinellida
Order	-	Amphidiscophora
Genus	-	*Hyalonema*

1. It is a marine sponge found along new England coast.
2. It is commonly called as 'glassrope sponge'.
3. It has a spherical or oval about 30 cm long body fastened in the mud by a root-tuft of long twisted spicules.
4. The spicules continue through the body as an axis or *columella* and often project above it as the *gastral cone.*
5. The gastral cone bears openings of the excurrent canals.
6. The surface may be depressed to enclose a cavity, the spongocoel, or may be flat in which case there is no spongocoel and the excurrent canals open out directly.
7. It possess large amphidisc spicules like fresh-water sponges. Entire body contains small, branching, six-rayed spicules.
8. The flagellated chambers are arranged radially and in parallel planes in the sponge wall.
9. Some anemones live attached to the root-tuft and certain crustaceans live inside the body as commensals.

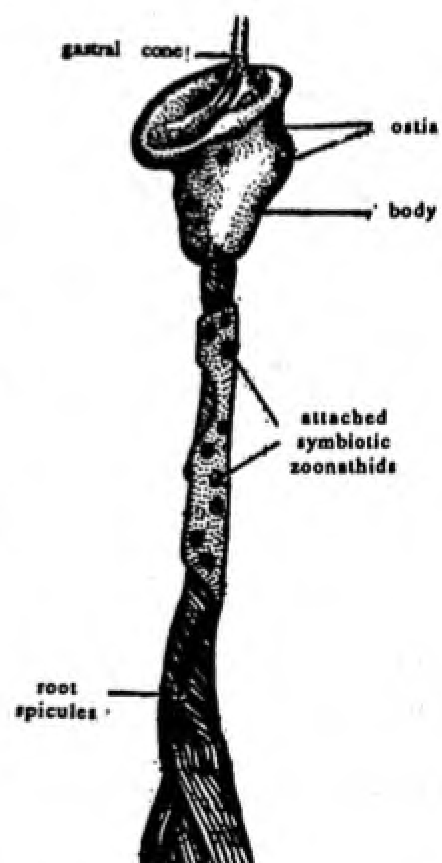


Fig. 15.19 *Hyalonema*

PHERONEMA

The classification is the same as that of *Hyalonema.*

1. It is found on the bottom of sea. It occurs in U.K., U.S.A. and Europe.
2. It has a cup or bowl-shaped body.
3. Body thick-walled with a large spongocoel, which opens above by an osculum.
4. Osculum is guarded by spicules or *marginal* prostals.
5. Glassy spicules project from the body surface, often in tufts called the *pleural prostals*, giving the appearence of glass wool.
6. Skeleton consists of amphidisc microsclers.
7. Canal system is of eurypylour leuconoid type.
8. Broad, ill-defined root-tufts made of silica, which are joined and serve for attachment to the substratum.

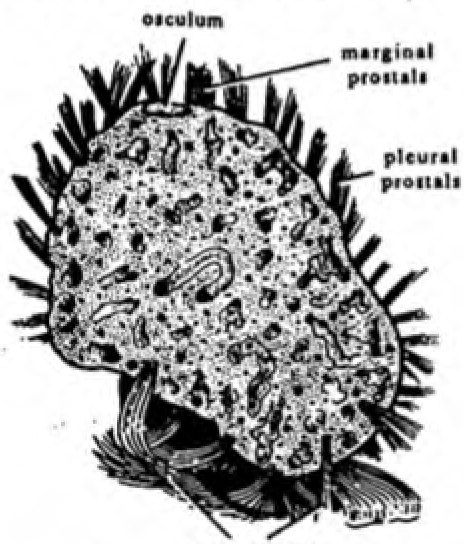


Fig. 15.20 *Pheronema*

16

LEUCOSOLENIA - AN ASCONOID SPONGE

Leucosolenia is one of the most simple sponge, growing in the sea-shore water. It belongs to the family Leucosolenidae. It is an asconoid sponge which resembles very much with the olynthus stage, found in the life cycle of certain other sponges like *Scypha*; as such it is also referred to as *olynthus-type*. Near about 100 species have been recorded uptil now, out of which *L. complicata*, *L. botryoides*, and *L. variabilis* are quite common. The description given below is the general one and is applicable to all the species.

SYSTEMATIC POSITION

Phylum	-	Porifera
Class	-	Calcarea
Order	-	Homocoela
Genus	-	*Leucosolenia*

HABITAT

Leucosolenia is a small marine sponge. It occurs almost all over the world in shallow water below low tide mark on rocks, stones and warfs. Though frail, it prefers places with intense wave action to calm waters. The wave action ensures adequate food supply and well-oxygenated water.

HABITS

Leucolosenia is a colonial sponge. The colony is permanently fixed to the substratum. It feeds on microscopic animals, plants and organic particles. Digestion is intracellular as in Protozoa. Reproduction occurs both asexually and sexually. Life-history includes a free-swimming flagellated larva for dispersal. The sponge is very sensitive to external conditions and dies if removed from its habitat. It has a good degree of power of regeneration.

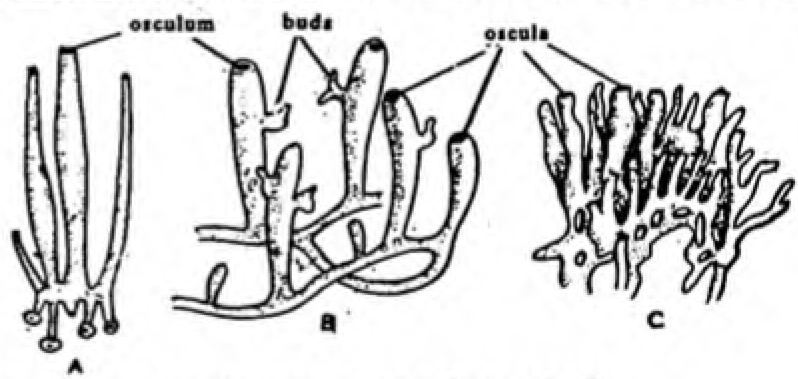


Fig. 16.1 Types of *Leucosolenid* A—Simple, B—Branching, C—Reticulate.

STRUCTURE

Types of Leucosolenia

A - Simple

B - Branched

C - Reticulate

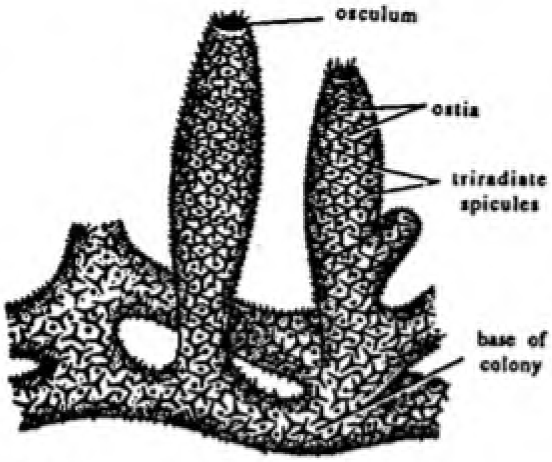


Fig. 16.2 *Leucosolenia*—A part of the colony

Shape and size. The colonies of *Leucosolenia* consist of numerous cylindrical structures each of which is a complete animal. It is a radially symmetrical animal. All the cylinders of the colony are attached to each other at the base due to which the colony appears as a thick branched bush-like structure. Each cylinder is about 25 mm long and whitish or yellowish in colour.

The cylinders of *Leucosolenia* are radially symmetrical thin walled tubes which represent the *Olynthus stage*. In the centre of each cylinder is a cavity called *spongocoel* which opens to the outside by a large aperture known as *osculum*. The wall of the cylinder is perforated by numerous pores which are intracellular and called *incurrent pores* or *ostia*. They lead into the spongocoel.

The *porocytes* are extremely elastic and close the ostia by contracting. The water current reaches the spongocoel through the ostia. The spongocoel is lined with choanocytes. The water of the spongocoel is expelled out through the *osculum* by the movement of the flagella of choanocytes, therefore, the structure of *Leucosolenia* is very simple.

BODY WALL

The body wall is thin with an outer epidermis or *pinacoderm* and inner endodermis or *choanoderm* with a non-cellular mesenchyme or *mesogloea* in between. The wall is perforated by numerous pores through which water enters the spongocoel and passes out through osculum.

1. *Pinacoderm* : The outer layer consists of a single layer of thin, scale-like, flattened cells called the *pinacocytes*. The cells have thin margins and a bulging central part with a nucleus. The margins show contractility so that the sponge can increase or decrease in size to some extent.

   Specially, large and tubular *porocytes* are also present which are supposed to be modified pinacocytes. Each porocyte has a central canal-like space which communicates with the exterior through ostia or dermal pores. Internally, they open into the spongocoel. The ostia are regulated by *myocytes* which form circlets around the openings.

2. *Choanoderm* : It consists of a single layer of flagellated cells or *choanocytes* which line the spongocoel. A choanocyte cell resembles the choanoflagellate protozoa. It is an ovoid cell, its free end bearing a transparent contractile collar which surrounds a single long flagellum arising from a basal granule. The nucleus lies at the centre

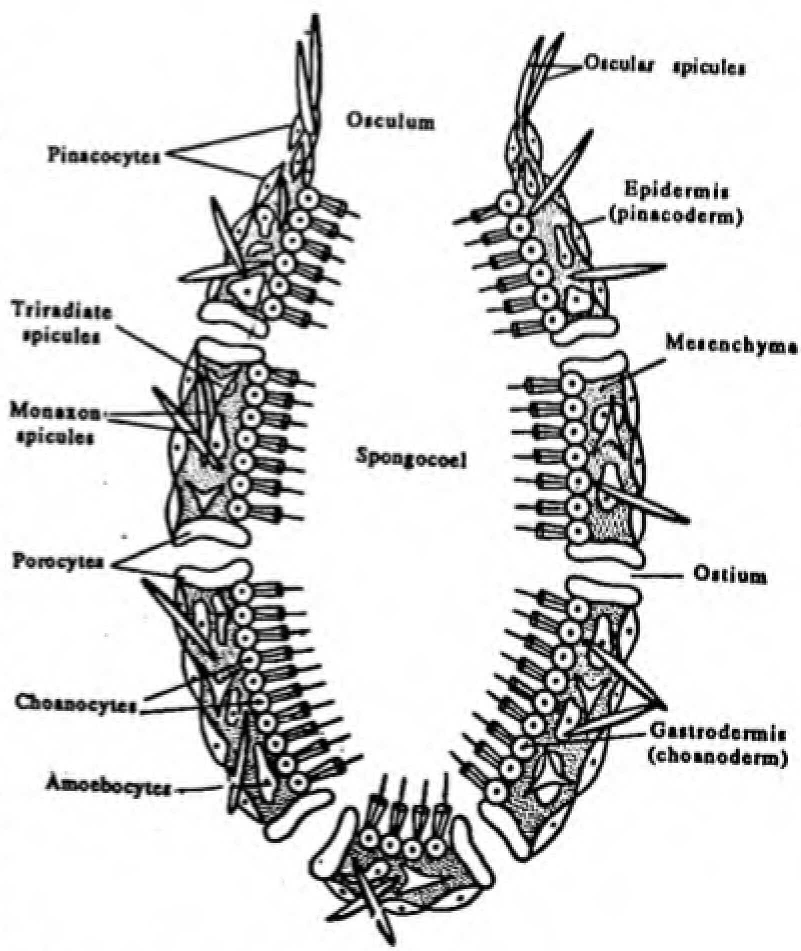


Fig. 16.3 L.S. of *Leucosolenia*

of the cell. These cells are used in feeding and for ensuring the flow of water within the animal's body.

3. *Mesenchyme* or *Mesogloea* : Mesenchyme lies between pinacoderm and choanoderm. It is a thin gelatinous layer secreted by the choanocytes and holds the spicules in space. Within the mesenchyme lie freely wandering amoeba-like, *amoebocytes* and the spicules.

The large primary amoebocytes with blunt pseudopodia and large nuclei are called *archaeocytes*, which are self replicating and give rise to all other types of amoebocytes. They also produce additional pinacocytes and choanocytes and the scleroblasts which form spicules and the reproductive cells. The archaeocytes carry on all the physiological activities of the sponge.

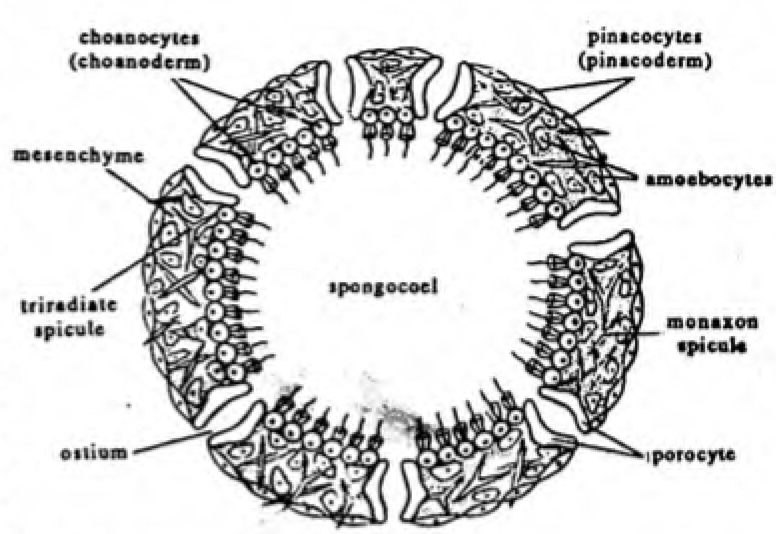


Fig. 16.4 *Leucosolenia* T.S.

The spicules, formed of crystalline calcium carbonate, may be needle-shaped monoaxons or tetraxons with four rays and triaxons with three rays. The spicules are embedded in the mesohyl but protrude out of the body to give roughness to the body.

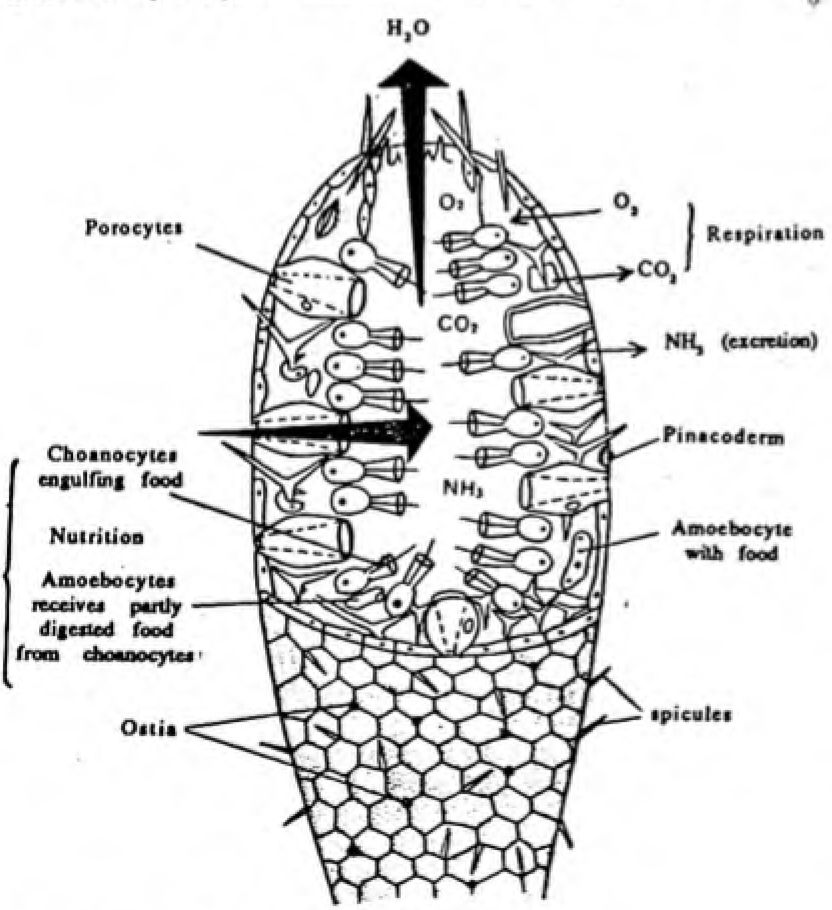


Fig. 16.5 Flow of water through the body

PHYSIOLOGY

The sponges being fixed animals are quiet and inactive-looking animals. Their physiology is mainly drawing a current of sea-water into their bodies.

The movement of the flagella of collar cells create the force, which draws a current of sea-water through the numerous dermal ostia into the spongocoel. The current brings with it minute organisms that constitute the food of the sponge. Flagellum of the collar cell stirs the food particles, which slowly settle down on the surface of the collar and over its basal part. Small pseudopodia-like processes of the basal part engulf the particles and form food vacuoles. Part or whole of the digestion takes place in the basal part and the products of digestion are then passed on to the amoeboid cells of the mesohyl, where digestion is completed. Digested food is transported to other parts of the body as the mesohyl cells move away. Amoebocytes pick up food particles directly. Such amoebocytes are located along the course of the canals in higher sponges. Undigestible material is thrown off into the spongocoel or into the space within the collar. Food is stored by specified amoebocytes termed *thesocytes*.

Water current not only brings food with it but also maintains a supply of fresh and oxygenated water. Oxygen diffuses into the cells with which the sea-water comes in contact. The water current leaves the spongocoel through the osculum and carries with it undigestible material, excretory products and carbon dioxide.

Sponges do not have nerve cells or sensory cells but are able to respond to the changes in salinity illumination and mechanical contact.

NUTRITION

The food of the animal comprises the microscopic animals, plants, and organic particles which are taken into the spongocoel along with the water and captured by the choanocytes from the moving water. In the choanocytes the food is partially digested and then this food is passed on to amoebocytes i.e. trophocytes where complete digestion takes place. These cells then distribute the digested food from cell to cell. Digestive enzymes, however, are more common in the choanocytes than they are in the amoebocytes (*Hartman* 1960). Egested waste is dropped by the amoebocytes into the water current.

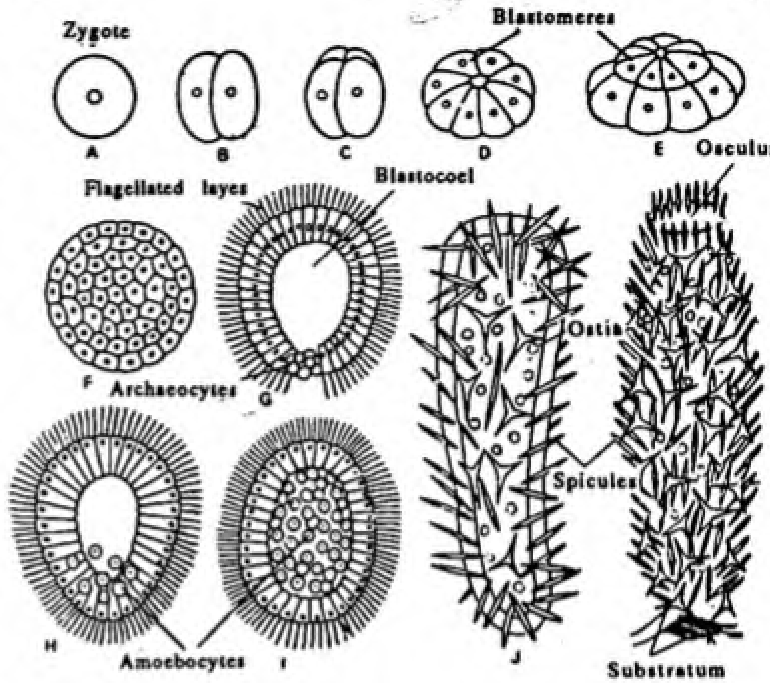


Fig. 16.6 Stages in the development of *Leucosolenia*

RESPIRATION AND EXCRETION

Gaseous exchange of oxygen and carbon dioxide occurs between the amoebocytes, choanocytes and pinacocytes and the water flowing through the canal system. Similarly nitrogenous wastes are voided.

LOCOMOTION

The sponges are fixed, as such they are incapable of movement. However, the porocytes can be opened and closed according to the needs, and the amoebocytes can also move freely within the mesenchyme.

BEHAVIOUR

There is no coordinating nervous system in the animal. The individual cell responds independently to the external stimuli. The flagella of the choanocytes beat constantly to cause a water current. Osculum may close independently without altering the activities of other structures. Induced prolonged contraction may cause the sponge to burst, indicating little co-ordination.

REPRODUCTION

Leucosolenia reproduces both by asexual and sexual means.

(a) Asexual reproduction. Asexual reproduction takes place by *external budding*. Small outgrowths, called the *buds*, arise from the sides of the erect branches as well as from the upper surface of the horizontal branches. The buds grow and, after attaining sufficient size, acquire osculum at their top, thus forming new individuals. The latter may remain attached to the parent colony and add to its size or become free by death and decay of old parts and form new colonies.

(b) Sexual reproduction. The sexual reproduction occurs by sperms and ova. Gamete formation and fertilization are similar in *Leucosolenia* and *Scypha* and will be described in the latter.

Zygote undergoes *holoblastic* cleavage and gives rise to an oval embryo called the *coeloblastula*. The latter is composed of a single layer of columnar flagellated cells with a few rounded, granular, non-flagellated cells at the posterior pole. The non-flagellated cells are thought to be the archaeocytes which will produce all future archaeocytes of the sponge. Some adjacent flagellated cells lose flagella and also migrate into the cavity. The embryo now consists of an outer layer of flagellated cells and an inner mass of amoeboid cells. It is known as the *stereogastrula* or *parenchymula*. It makes its way into the spongocoel and escapes through the osculum into the surrounding water, thus becoming a free-swimming larva.

The *parenchymula larva* swims about freely for a few hours, going away from the parent sponge. Finally, it fixes itself to some object by its anterior pole and flattens out. The internal amoebocyes migrate to the exterior and spread out to form a dermal layer or epidermis and mesenchyme. The flagellated cells, which get enclosed by the epidermis, change into choanocytes. A central cavity or spongocoel appears and gets lined by choanocytes. An osculum breaks through at the top and incurrent pores or ostia appear in the porocytes that differentiate in the wall of the sponge by this time. Scleroblasts shift from the epidermis into the mesenchyme and start secreting spicules. This results in a small sponge and takes only a few days.

17

SCYPHA (SYCON)

SYSTEMATIC POSITION

Phylum	-	Porifera
Class	-	Calcarea
Order	-	Heterocoela
Genus	-	*Scypha (Sycon)*

HABITS AND HABITAT

Scypha is more complex than *Leucosolenia. Leucosolenia* shows primitive asconoid type of structure while in *Scypha*, there is folding of body wall to show syconoid type of structure where the spongocoel is reduced. *Scypha* is a small, marine sponge found attached by a sticky secretion to some submerged solid objects like rocks, shells of molluscs and corals. It is found in shallow water upto a depth of 100 meters where waves provide the animal with plenty of food and well oxygenated water. It has many species and is widely distributed but is best, known from North Atlantic shores. It may be solitary but also forms a cluster or colony by budding.

Fig. 17.1 *Scypha (Sycon)*

EXTERNAL MORPHOLOGY

Scypha or *apycon* possesses a vase-shaped and radially symmetrical body which measures from 1 to 3 cm in length. The colour is not specific but varies from grey to light brown. Near the attached end are found a few small tubular projections, or the *buds*, which are formed not so extensively as in *Leucosolenia* or other asconoid sponges. The free end of the vase-shaped individual bears an opening, the *osculum* (*exhalent* or *excurrent* pore), which is fringed with long, straight, needle-like monoaxon spicules. This *oscular fringe* checks small animals from entering into the body. The body surface is thrown into regularly arranged polygonal elevations from which project spear-like spicules, called *oxeotes* (monaxon spicules) that impart a bristly appearance to the body. The polygonal elevations are separated by deep grooves, bearing minute pores, i.e., the *ostia*, which lead into the central body cavity, the *spongocoel* or *paragastric cavity*, through a system of canals.

CANAL SYSTEM

As in other sponges, *Scypha* has the peculiarity of having canal system which consists of complex system of pores and canals. The body is traversed by numerous canals of several types. The body wall is thick and folded so as to form regularly arranged alternating invaginations and evaginations, forming sycon type of canal system. The different components of canal system of *Sycon* are given below.

1. **Ostia or dermal pores.** The external large openings of the incurrent canals are stretched over a thin membrane, called the *pore-membrane*. It bears two or more openings for the ingress of outside water into the body of sponge. These pores are known as *ostia* (L., *ostium*, door) or *dermal pores*. Because of the presence of contractile cells the *myocytes*, around them

the ostia can reduce in diameter and thus regulate the amount of ingressing water.

2. **Incurrent canal.** The incurrent canals are narrow and almost squarish in cross-section. They end blind at their inner extremities, a little distance away from the spongocoel. Externally they become somewhat dilated. The dilated part of each canal is closed externally by a thin *pore-membrane* that bears 3 or 4 minute openings, the *dermal ostia*, already referred to. The pore membrane also contains myocytes, some of which surround the dermal ostia and serve to close them when necessary. The incurrent canals are lined by flat pinacocytes similar to those lining the spongocoel.

3. **Radial canals.** The radial canals are relatively wide and are polygonal in cross-section. They are closed at their outer ends which lie some distance inside the polygonal surface elevations. Internally they open into the excurrent canals by apertures called *apopyles*. An apopyle is a large circular opening in the centre of a thin partition, the *diaphragm*, that stretches between the adjoining radial and excurrent canals. It can be contracted or dilated by myocytes that border it. The radial canals are lined by a layer of loosely arranged, flagellated, collar cells known as the *choanocytes*. The latter resemble the choanoflagellate Protozoa. A choanocyte is a somewhat oval or rounded cell that contains a nucleus and one or more vacuoles and bears at its inner end a long, whip-like, vibratile flagellum partly surrounded by a delicate, transparent, contractile collar. The collar is formed by side-to-side fusion of 20-30 processes from the cell. The flagellum arises from a prominent organelle, the *centroblepharoplast*, situated within the cell. It is a combination of the centriole and the blepharoplast. It is connected by a thread, the *rhizoplast* with another organnelle, the *parabasal body*, lying on the nucleus. The incurrent canals communicate with the radial canal by short narrow channels called the *prosopyles*.

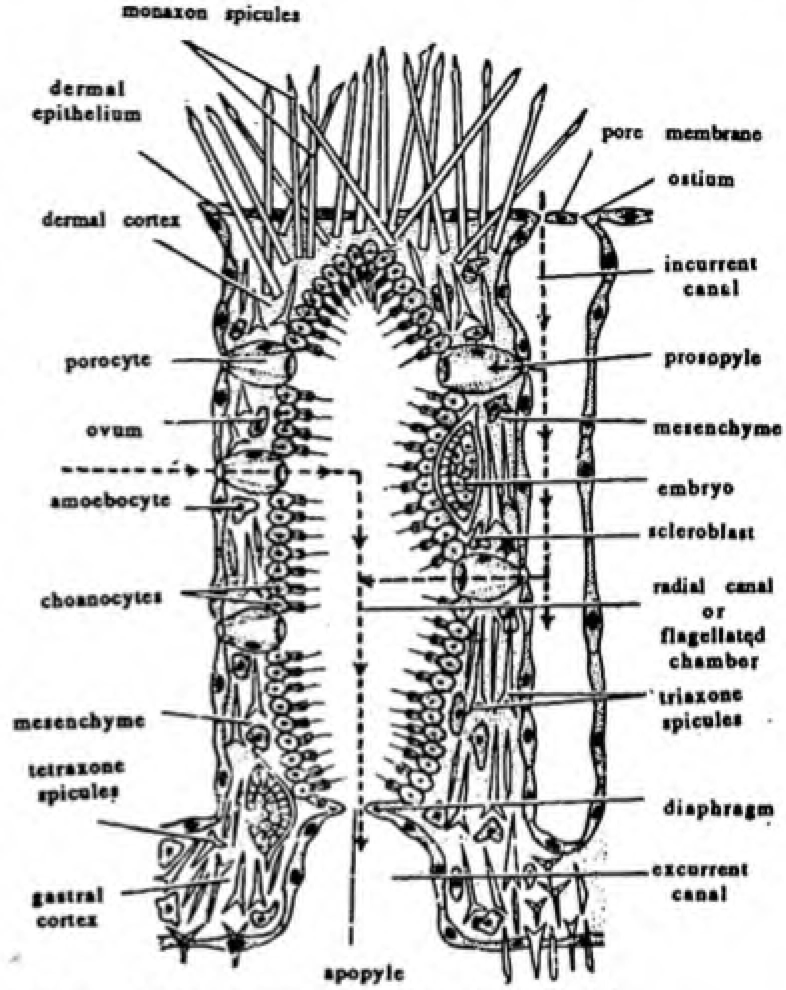


Fig. 17.2 A part of vertical section of *Scypha* showing histology and canal system.

4. **Prospyles.** The incurrent canals are communicated with the radial canals through intercellular spaces, called *prosopyles* (Gr., *pros*, near + *pyle*, gate). Some authors are of view that in the young *Sycon* these openings are those of the porocytes, as in *Leucosolenia*, but in adult the porocytes degenerate leaving the empty spaces or the prosopyles.

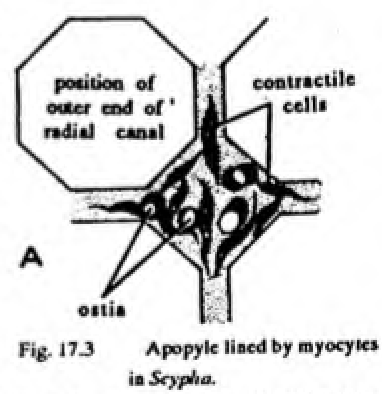


Fig. 17.3 Apopyle lined by myocytes in *Scypha*.

5. **Excurrent canals.** Each excurrent canal leads the radial canal into the spongocoel and forms a wide and short passage between the radial canal and spongocoel. These are lined with flat ectodermal cells like that of the spongocoel. The excurrent canal opens into the spongocoel through wide gastric ostium. Between the radial canal and excurrent canal lies a thin diaphragm perforated by a large hole known as *apopyle* which is surrounded by contractile myocytes.

6. **Spongocoel.** It is the central cavity of the body and, unlike *Leucosolenia*, is not lined by the flagellated collar cells or *choanocytes*, which have departed to line the radial canals, while the epidermal pinacocytes have immigrated into the spongocoel (Gr., *spongos*, sponge + *koilos*, hollow) to form its lining. This cavity is comparatively a narrow cavity.

7. **Osculum.** The spongocoel leads to outside through a terminal opening, the *osculum*. The oscula are provided with *sphincters* to regulate the rate of water flow in the body. The sphincters are lined by special contractile pinacocytes called *myocytes* (Gr., *Myos*, muscle + *kytos*, cell).

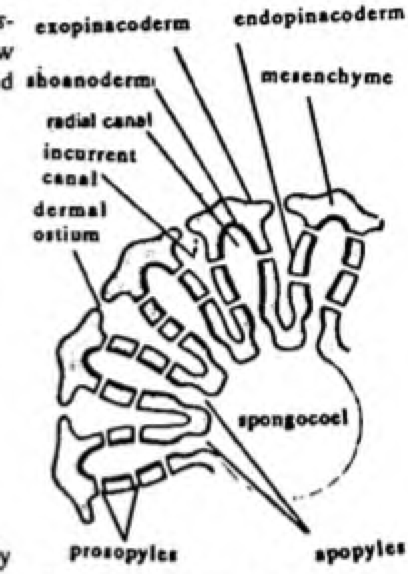


Fig. 17.4 A portion of a T.S. of *Scypha*

Water from outside	$\xrightarrow[\text{dermal ostia}]{\text{through}}$	incurrent canals	$\xrightarrow[\text{prosophles}]{\text{through}}$	radial canals ↓ through
outside	$\xleftarrow[\text{osculum}]{\text{through}}$	spongocoel	$\longleftarrow$	epopyles

The course taken by water into the canal system is as under:

PHYSIOLOGY OF THE WATER CURRENT

The flagella of the collar cells beat without coordination yet maintain a steady current of water flowing in the sponge from outside. The current enters the pores in the pore-membrane of the incurrent canals and fills the latter, it then passes into the flagellated canals through the prosopyles. From here it goes into the excurrent canals by way of apopyles. Finally, the current is thrown into the spongocoel by the large gastric ostia from where it escapes through the osculum. The osculum is also surrounded by myocytes serving to form an *oscular sphincter*, which can close the osculum.

The water current flowing through the canal system brings with it food in the form of micro-organisms and oxygen. The food, chiefly unicellular algae, bacteria and organic microfragments, is collected by the collar cells just the same way as described for *Leucosolenia*. The out going current carries with it undigestible wastes and nitrogenous excreta.

CELLULAR ORGANIZATION

Studies on structure and morphogenesis of *Scypha* have clearly revealed the presence of two types of cellular layers, the *pinacoderm* and the *choanoderm*. The former controls the interrelations between the mesenchyme and the external medium, while the later controls mainly the nutrition of the animal.

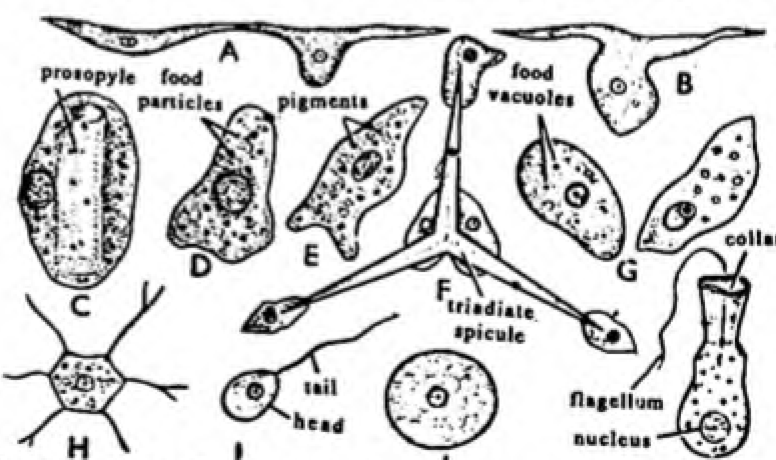


Fig. 17.5 *Scypha*. Kinds of cells. A—Pinacocytes. B—Myocyte. C—Porocyte. D—Thesocyte. E—Chromcyte. F—Sclerocytes. G—Archaeocytes. H—Collencyte. I—Sperm. J—Ovum. K—Choanocyte.

1. Pinacoderm

The pinacoderm comprises (i) the *exopinacoderm* (dermal epithelium) covering the entire body surface except the dermal ostia and osculum and (ii) the *endopinacoderm* which includes the epithelial lining of the incurrent canals and spongocoel. The pinacoderm is composed of large, flattened, polygonal cells, the *pinacocytes* (Gr., *pinako*, plank + *kytos*, cell). In profile, these cells present a central bulging containing the nucleus. The margins of adjacent cells are closely cemented together. Pinacocytes are highly contractile and they can greatly increase or reduce the surface area of the sponge body.

In the lining of the incurrent canals, some of the pinacocytes are modified to form tubular cells, the *porocytes*, connecting the incurrent canals with the radial canals through their intracellular channels, the *prosopyles*. The porocytes are thin-walled cells, open at both ends and with the nucleus present in the peripheral cytoplasm. As has already been noted, the porocytes in the adult sponge are lacking altogether. Pinacocytes surrounding the osculum, outer or dermal ostia and inner ostia or apopyles are elongated and contractile and act as muscle cells, called the *myocytes*. They form the sphincters around them to regulate these openings.

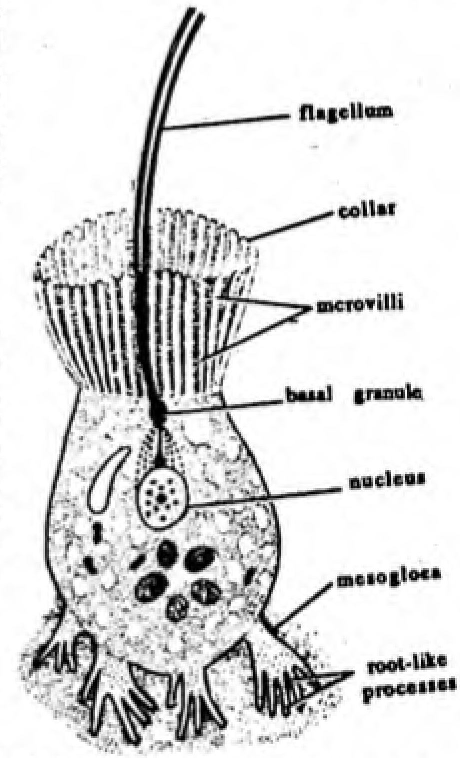


Fig. 17.6 Ultra Structure of a *Choanocyte*.

2. Choanoderm

This is the endoderm that forms the gastric epithelium and consists of flagellated collar cells or *choanocytes*. They are oval or rounded cells arranged upon the mesenchyme. Each cell contains a single nucleus, one or two contractile vacuoles, food vacuoles, reserve food, blepharoplast, rhizoplast and a single basal granule or kinetosome from which whip-like flagellum arises. The flagellum is surrounded at its base by a thin cytoplasmic collar. The flagellum has two central fibrils and nine double peripheral fibrils. The collar of the flagellum is contractile and is made up of a ring of erect and closely set microvilli which project from the cell. The choanocytes line the radial canals or flagellated chambers. The movement of these flagella causes a current of water.

3. Mesenchyme

The mesenchyme which fills the space between the two body layers is composed of a thin gelatinous matrix which contains many kinds of amoeboid cells such as :

(i) *Collencytes* - Star-shaped cells which are sometimes united to form a network.

(ii) *Chromocytes* - Pigmented cells with lobose pseudopodia. They probably impart colour to the sponge.

(iii) *Thesocytes* - Cells with lobose pseudopodia and are laden with reserve food material.

(iv) *Scleroblasts* - These secrete the spicules.

(v) *Trophocytes* - They are loaded partly or completely with digested food. They serve to transfer food from one place to another.

(vi) *Phagocytes* - These cells collect food from the choanocytes through their pseudopodia and also engulf excreta and damaged tissues.

(vii) *Archaeocytes* - or undifferentiated embryonic cells that give rise to sex cells.

(viii) *Lophocytes* - These are amoeboid cells with a tuft of fibrils at one or both ends and occurs in connection with the pinacocyte epithelium. Its function is unknown but it may secrete fibrillar bundles.

(ix) *Desmocytes* - They are long slender cells lying at the basement of the canals.

(x) *Gland cells* - They are derived from amoebocytes and secrete mucous.

(xi) *Germ cells* - Some of the amoebocytes (archaeocytes) differentiate into sex cells i.e. ova or sperms. However, in some sponges, they are said to be modified choanocytes.

(xii) *Myocytes* - Around the apopyles, osculum, and ostia are also present a number of narrow elongated highly contractile cells, the *myocytes*.

The mesenchyme also contains the spicules which are monaxonic and triradiate in form. These serve to strengthen the body and hold it up right.

SKELETON

The skeleton of *Sycon* consists of calcareous spicules having crystalline appearance which supports and protects the soft parts. They have an axis of organic material around which is deposited the inorganic substance i.e. calcium carbonate or hydrated silica. The spicules are secreted by sclerocyte cells and each ray of the spicule is said to be secreted by two such cells. The sclerocytes are in their turn produced by scleroblast cells. Spicules of *Sycon* show a variety of shapes and sizes and have a particular arrangement with regard to their canal system. The following are the main types of spicules :

(i) Large single rayed, needle-shaped *monaxon spicules* arranged in a circlet around the osculum, (ii) Simple spear-like monaxon spicules projecting from dermal cortex opposite the outer ends of the radial canals, (iii) *Triaxon* or three rayed spicules are present along the radial canals with their one end pointing towards the distial ends of the canals, (iv) Four rayed, *tetraxon spicules* are present in the thick gastral cortex alongwith triaxon spicules and surround the spongocoel. Thus the long monaxons surround the osculum in the form of oscular fringe while the short monaxons lie parallel to the radial canals. The triradiates mostly lie along the radial canals with one ray facing externally. The tetraradiate spicules also lie in the same region.

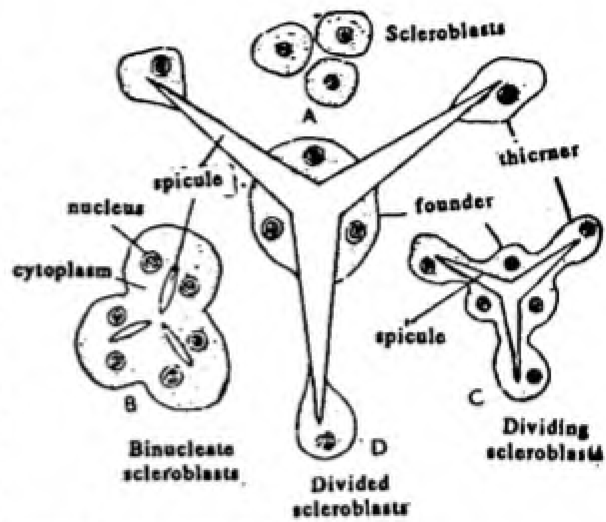


Fig. 17.7 Secretion of a *triradiate spicule.*

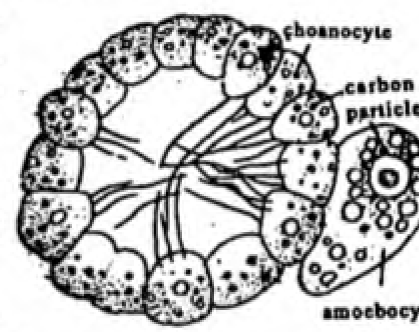


Fig. 17.8 *Amoebocytes* receiving carbongrains from choanocytes.

NUTRITION

Nutritionally, *Scypha* is both holozoic and saporozoic. Its food consists of microscopic organisms, organic debris and *detritus.*

Ingestion takes place in an interesting way. The ceaseless, though uncoordinated, beating of the flagella of the choanocytes set up a water current that draws the food particles into the radial canals through the dermal ostia, incurrent canals and prosopyles. The flagellum undulates from the base to the tip and this creates a current that starts from the base of the flagellum and passes towards its tip. This in turn draws the food particles towards the collar, because it surrounds the base of the flagellum and here they adhere to its outer sticky surface. These particles are then engulfed by pseudopodia arising from the choanocyte at the base of its collar.

Digestion in *Scypha* is completely intracellular and occurs in food vaculoes in much the same way in Protozoa. Enzymes socreted in the food-vacuoles by the surrounding cytoplasm gradually digest the food. Food contents of the vacuoles are first acidic and later become alkaline. This corresponds to the acidic phase of digestion in the stomach and alkaline phase in the intestine of higher animals. All the 3 types of enzymes, *viz., proteases, carbohydrases* and *lipases*, have been isolated, but it is not certain whether they are secreted by *Scypha* itself or by bacteria that about in it.

Distribution of digested food to other cells (pinacoctyes, myocytes, porocytes, etc.) is affected in two ways : by cell to cell diffusion and by amoebocytes, called *trophocytes,* that take up wholly or partly digested food from the choanocytes and move about in the mesogloea, delivering nutrient to various cells.

Storage of food occurs in certain amoebocytes, called *thesocytes,* in the form of glycogen, fat, glycoprotein or lipoprotein.

Egestion is brought about by choanocytes and amoebocytes that throw off indigestible pieces into the canals, from where they are ultimately driven out through the osculum by the outgoing current of water.

SENSITIVITY

Sponges do not have a nervous system and their responses are mainly local. The osculum is the most sensitive part, it collapses when the incoming current is polluted, or a strong beam of light is focussed over it or, when the sponge is partly submerged or is touched by some object. It seems that under the influence of a stimulus myocytes contract causing the closure of the osculum. The stimulus then gradually passes down the cylinder for a short distance probably by means of the mesh of neurons. Myocytes are probably *neuromuscular cells*. Occurrence of bipolar and multipolar nerve-cells, the *neurons*, has been claimed by *P. de Cewatty* (1955) in the mesohyl beneath the dermal membrane of certain sponges. In a few species of Demospongiae and Calcarea *lophocytes* are believed to serve a sensory function (*W.C. Jones* 1962). Whether or not, there are nerve-cells in sponges, their responses are so simple that one sometimes doubts the necessity of nerve cells. For instance, a sponge named *Oscarella lobularis* responds to varying light intensities; it becomes deep red in light and turns brown in dark. The significance of this change is unknown, but it occurs slowly and does not seem to be controlled by nerve cells. Similarly many sponges secrete lot of slime when lifted out of water. It is perhaps a direct response of pinacocytes at the surface to a change in their environment. It does not call for a nervous system.

Respiration

Respiration is aerobic and is accomplished externally by the general body surface or pinacocytes and internally by choanocytes and lining cells. Each cell respires for itself, oxygen entering the cell and carbon dioxide leaving the cell by simple diffusion. Amoebocytes distribute oxygen within the mesenchyme and carry away carbon dioxide. The entire process is again *intracellular*.

Excretion

The nitrogenous waste is ammonia for most part and in all probability it leaves the cell by diffusion. It has also been claimed by some investigators that the nitrogenous wastes first are taken up by the amoebocytes which are then discharged into the spongocoel, from where they pass out in the water current through osculum.

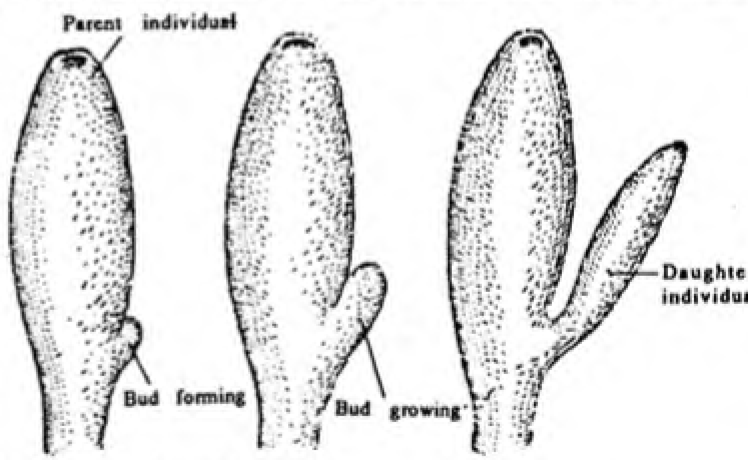


Fig. 17.9 Bud formation in *Scypha*.

Reproduction

Scypha reproduces asexually as well as sexually as given below :

1. Asexual Reproduction

(i) ***Budding*** - It is a very common method of asexual reproduction. Masses of archaeocytes migrate to the tips of spicules clumps that project from the surface in the form of bud. These buds either remain attached and grow in size, thus increasing the bulk of the sponge or it may finally breaks up and form new sponge.

(ii) ***Regeneration*** - Regeneration is the power to replace the parts lost by injury. The power of regeneration has developed to such an extent that if a sponge is thoroughly teared or squeezed in the sea water so as to separate the cells from one another, it is found that the cells slowly come together and gradually form a young sponge again.

2. Sexual reproduction

Scypha is a *monoecious* sponge but due to *protogyny*, only cross-fertilization occurs. Special sex organs are lacking. Male sex cells, the *sperms* and the female sex cells, the *ova*, are found in the mesenchyme. They develop from undifferentiated amoebocytes, called *archaeocytes*.

(a) *Spermatogenesis*. The sperm mother cell or *spermoatogonium* is said to be an enlarged archaeocyte. However, it is supposed to be a modified choanocyte by *Gatenby*, who described the transformation of an entire flagellated chamber into spermatozoa. Soon the spermatogonium is surrounded by one or more flattened *cover cells* to form the *spermatocyst*. The cover

cells are derived either by the division of the mother cell or from other amoebocytes. The spermatogonium undergoes two or three divisions to form the *spermatocytes* which give rise to *spermatozoa*. A mature sperm or *spermatozoon* consists of a rounded, nucleated head and vibratile tail, by the lashing movements of which it moves in water to reach other sponges.

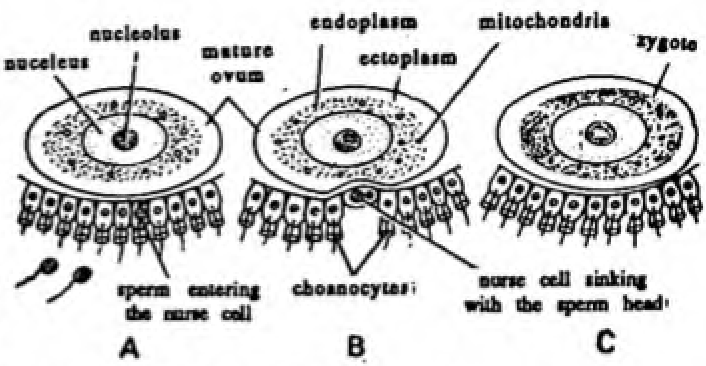


Fig. 17.10 Stages in fertilization in situ in a *calcarean sponge*.

(b) *Oogenesis*. The egg mother cell or *oogonium* is derived from a large archaeocyte with a distinct nucleus. This may sometimes arise by transformation of a choanocyte which store some food, loses its flagellum and sinks into the amoebocyte and grows by engulfing other cells which may be amoebocytes or special nurse cells (*trophocytes*). The oogonium gives rise to an oocyte. When full grown, the oocyte undergoes the usual two maturation divisions to form the *ovum* which lies in the wall of a radial canal, ready to be fertilized by a sperm from another sponge.

Fertilization

Fertilization is internal. When the sperms mature, the spermatocysts rupture, discharging the sperms into the radial canals. From here, they are carried by the outgoing current of water to the exterior through the osculum. With the incoming water current, the sperms enter another sponge through the dermal ostia and reach the radial canals. Here, each sperm enters a wandering amoebocyte or a choanocyte. The invaded choanocyte loses the flagellum, withdraws the collar, becomes amoeboid and migrates into the mesogloea. The amoebocytes and choanocytes penetrated by the sperms are known as the *sperm-transit cells*, as they serve to carry the sperms to the ova through the mesogloea. A sperm-transit cell adheres to a nearby ovum, which forms a conical depression to receive it. The sperm loses its tail and its head swells up. The swollen head gets surrounded by a capsule. The capsule with the sperm head entres the ovum. This completes the act of fertilization and results in the formation of a *zygote*. The sperm transit cell now departs. The zygote gets enclosed in a *brood capsule* formed by lining up of the neighbouring amoebocytes. Early development of the zygote occurs within the brood capsule of the parent.

Development

The development of *Sycon* includes the early embryonic period and larval period followed by metamorphosis.

I. Embryonic period

(a) *Cleavage*. The fertilized egg undergoes maturation and starts development within the mesenchyme of the parent. It undergoes equal and *holoblastic cleavage*. The first three cleavages are verticle forming 8 blastomeres. The horizontal division then divides the blastomeres unequally and of the 16 blastomeres produced, 8 are large cells or *macromeres* lying next to the parent choanoderm. They are designed to form future epidermis. Eight smaller cells or *micromeres* give rise to future choanocytes. At this stage, the embryo lies just

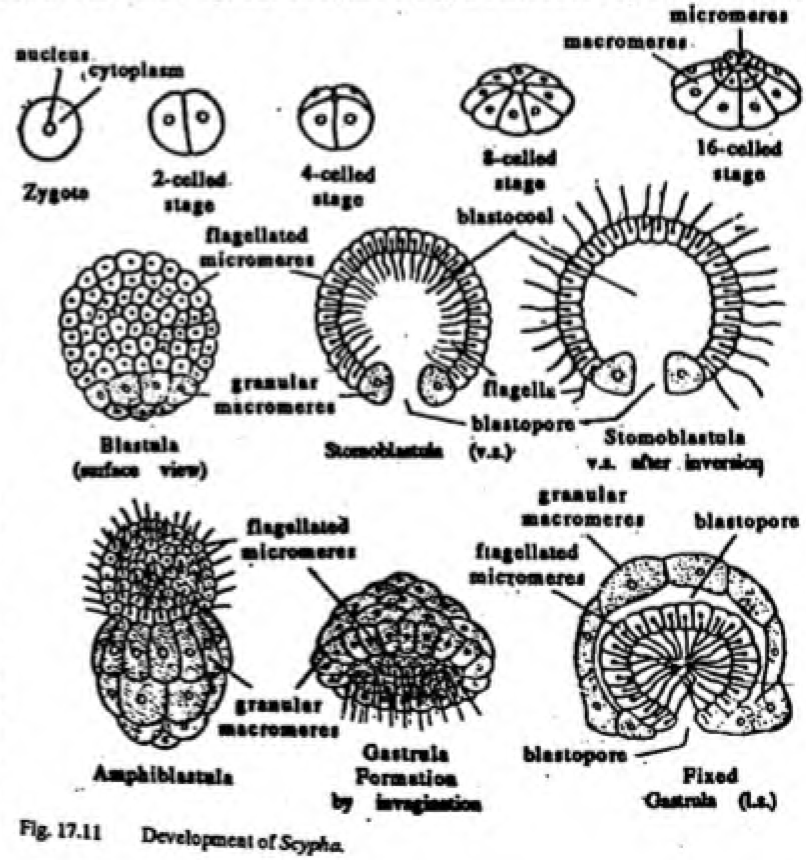


Fig. 17.11 Development of *Scypha*.

beneath the maternal choanocyte layer as a flattened disc-shaped body. The micromeres undergo rapid mitosis to form several micromeres, elongate and each develops a flagellum on its inner end facing the blastocoel. The macromeres do not divide for sometime, become rounded and granular and an opening is formed in their middle which helps in the ingestion of adjacent maternal cells. This stage may be called as *blastula* with a blastocoel between both the tiers.

(b) *Stomoblastula*. In the stomoblastula, its one side is composed of many small, elongated and flagellated *micromeres* and the other side is composed of eight rounded cells called *macromeres*. The blastocoel communicates to outside through an opening, the *mouth*, between the macromeres. This mouth is used for engulfing the surrounding amoebocytes for nutrition.

(c) *Amphiblastula* - The columnar flagellated cells of the stomoblastula continue to multiply. As a result of the pressure exercised, the entire embryo turns inside out by the mouth so that the flagella now point outwards. After this inversion, the macromeres, also multiply and as they progress on all sides, the mouth of the larva is closed. As a result of further multiplication of cells, the larva becomes slightly elongated. A pigment and an eye spot develop at the anterior pole. This is the typical flagellated *amphiblastula* larva of class Calcarea. It is enclosed in a *trophic membrane* of maternal choanocytes which supply food to the growing embryo. It is oval in shape having one half of it made of small, narrow flagellated micromeres and the other half having large, rounded, non-flagellated macromeres.

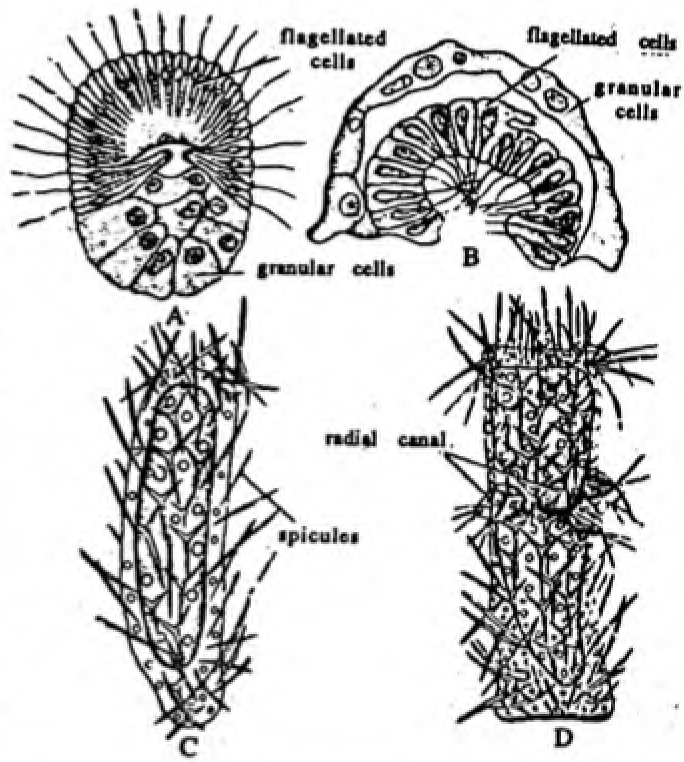


Fig. 17.12 Later stages of development of *Scypha*.

(d) *Gastrula*. Ultimately the ambiblastula settles down and undergoes gastrualtion. The macromeres multiply more rapidly than the micromeres, so that the flagellated half of the larva is invaginaged into and overgrown by the granular non-flagellated half. The larva now becomes a typical double-walled *gastrula* with a *blastopore* at the invaginated side.

II. Metamorphosis

After swimming for some time, the flagellated half of the larva invaginates into or is overgrown by the large non-flagellated cells. With this process, the single-layered amphiblastula larva changes into a two layered *gastrula* with an opening, the *blastopore*, at the invaginated end. Outer layer of the gastrula consists of the non-flagellated granular cells and the inner of the flagellated cells. Gastrulation, thus, in a way reverses the inversion that took place at the stomoblastula stage.

The gastrula soon fixes itself to some substratum by its blastoporal end and grows into a cylindrical structure. Its blastopore closes by the growth of both the layers of cells along the substratum. At its free end develops a perforation which becomes the osculum. The outer non-flagellated cells flatten to form the dermal layer of pinacocytes. The inner flagellated cells for a time line the entire cavity which is the future spongocoel. Pores appear in the sides of the cylinder and start functioning as the dermal ostia. Through them water enters the spongocoel and leaves it through the osculum. At this stage the young sponge resembles just as - conoid sponge *Leucosolenia*. This is known as the *olynthus stage*. The wall of the cylinder gradually thickned due to the formation of mesogloea between the two layers of cells. Evagination from the spongocoel gives rise to the radial canals and invaginations of the dermal layer form the incurrent canals. The radial canals alone retain the flagellated cells, which by now become the choanocytes. In the mean time, spicules and various types of amoebocytes are differentiated in the mesogloea. The scleroblasts and myocytes are derived from the non-flagellated layer, while the archaeocytes and other amoebocytes develop from the flagellated layer of the larva. The mesenchyme cells are, thus, differentiated from both the germ layers. With all this, a young *Scypha* comes into being.

18

HISTOLOGY OF SPONGES

In most of animals the body is composed of various tissues like epithelium, connective, muscular, nervous and skeletal. But in sponges there is cellular grade of organization means the body is composed of different types of cells lacking proper organization. The cells found in sponges do not organize into tissues. Sponges are diploblastic i.e. composed of two layers - *ectoderm* or *dermal epithelium* and inner *endoderm*. In between these layers lies *mesenchyme*.The cells of these layers are simple and modified according to their function.

(1) ECTODERM

These cells are generally called *dermal epithelium*. They form a covering of the outer body surface and the lining of incurrent canals. The following cells form this layer :

(i) *Pinacocytes*. These are large flat, closely cemented cells with thickned central bulge containing the nucleus. They appear continuous with adjacent cells. These are generally found to cover the outer body surface when they are called *dermal epithelium*. In syconoid sponge they also line the paragastric cavity here they are called *gastral epithelium*. These cells are highly contractile and thus can reduce the surface area.

In some sponges the epidermis is formed by epitheloid membrane which is a continous membrane having numerous scattered nuclei.

Hexactinellid sponges have no definite epidermis.

(ii) *Porocytes*. In asconoid sponges (*Leucosolenia*) some of the pinacocytes are modified to form tubular cells, the *porocytes*, connecting the incurrent canals with the radial canals through their intracellular channels, the *prosopyles*. The porocytes are thin-walled cells, open at both ends and with nucleus present in the peripheral cytoplasm. As has already been noted, the porocytes in the adult sponge are lacking altogether. Pinacocytes surrounding the osculum, outer or dermal ostia and inner ostia or apopyles are elogated and contractile and act as muscle cells, called the *myocytes*. They form the sphincters around them to regulate these openings.

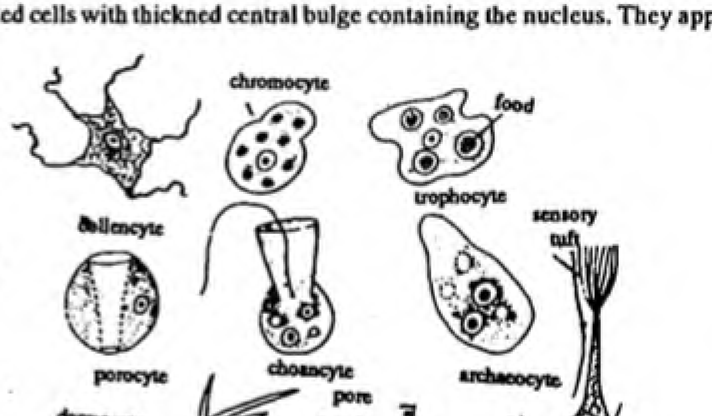


Fig. 18.1 Types of cells in a *sponge*.

(2) CHOANODERM OR ENDODERM

Choanoderm or endoderm forms the gastric epithelium and consists of flagellated collar cells or *choanocytes*.They are oval or rounded cells arranged upon the mesenchyme. Each cell contains a single nucleus, one or two contractile vacuoles, food

vacuoles, reserve food, blepheroplast, rhizoplast and a single basal granule or kinetosome from which whip-like flagellum arises. The flagellum is surrounded at its base by a thin cytoplasmic collar. The flagellum has two central fibrils and nine double peripheral fibrils. The colar of the flagellum is contractile and is made up of ring of erect and closely set microvilli which project from the cell. The choanocytes line the radial canals or flagellated chambers. The movement of their flagella causes a current of water

(3) MESENCHYME

The gelatinous, transparent matrix of mesenchyme is known as mesogloea in which are found special cells called *amoebocytes* which may be of the following type:

(i) *Collenocytes.* Star-shaped cells which are sometimes united to form a network.

(ii) *Chromocytes.* Pigmented cells with lobose pseudopodia. They probably impart colour to the sponge.

(iii) *Thesocytes.* Cells with lobose pseudopodia and are laden with reserve food material.

(iv) *Scleroblasts.* These secrete the spicules. They may be *calcoblasts* (secreting calcareous spicules), *silicoblasts* (secreting siliceous spicules) and *spongioblasts* (secreting spongin fibres).

(v) *Trophocytes.* They are loaded partly or completely with disgested food. They serve to transfer food from one place to another.

(vi) *Phagocytes.* These cells collect food from the choanocytes through their pseudopodia and also engulf excreta and damaged tissues.

(vii) *Archaeocytes.* Or *undifferentiated embryonic cells* that give rise to sex cells. They have blunt pseudopodia, large nuclei, conspicuous nucleolar and cytoplasmic inclusions. They may also be associated with transport of food and waters.

(viii) *Lophocytes.* These are ameoboid cells with a tuft of fibrils at one or both ends and occurs in connection with the pinacocyte epithelium. Its function is unknown but it may secrete fibrillar bundles.

(ix) *Desmocytes.* They are long slender cells lying at the basement of the canals.

(x) *Gland cells.* They are derived from amoebocytes and secrete mucous.

(xi) *Germ cells.* Some of the amoebocytes (archaeocytes) differentiate into sex cells i.e. ova or sperms. However, in some sponges, they are said to be modified choanocytes.

(xii) *Myocytes.* These are elongated, narrow nucleated cells arranged around the apopyles, osculum, and ostia are also present a number of narrow elongated highly contractile cells, the myocytes.

By their contractibility they can control the size of the openings.

The mesenchyme also contains the spicules which are monaxonic and triradiate in form. These serve to strengthen the body and hold it up right.

CANAL SYSTEM IN SPONGES

All the activities of the body of the sponges depend on the current of water entering through ostia and passing out through osculum or oscula. Inside the body, water current flows through system of spaces which collectively constitute the canal system. The entire physiological activities of the animal depend on the water current as the exchanges between the body and the exterior are maintained through this water current. The food and oxygen are brought through this current while excreta and reproductive bodies are excluded through this current. The perforations of the body of the sponge by a large number of ostia is characteristic of phylum Porifera.

The arrangement, and complexity of the canal system varies considerably in different animals but has been divided into four types:

1. Ascon type
2. Sycon type
3. Rhagon type
4. Leucon type

All the living tissues of the sponges are soft and it is a direct need of the animal to maintain a constant shape with different canals or passage-ways, Therefore, deeper layers of the body are provided with supporting *spicules*. Around the osculum, spicules are long and straight, while spicules situated around ostia are short and straight; around spongocoel they are Y-shaped, while trirayed in the boyd-wall.

Thus, all the activities of sponges with intricate passages of canals, traversed by currents of water entering by pores and passing out by osculum are collectively termed as a canal system of sponges.

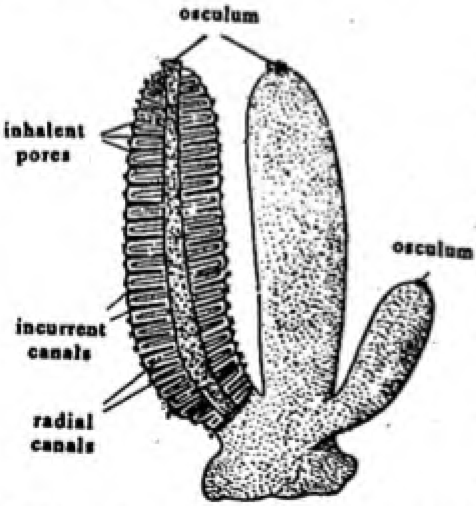


Fig. 19.1 *Sycon gelatinosum* showing paragastric cavity, incurrent and radial canals.

A typical canal system is composed of following components:

(a) *Incurrent canal.* It opens externally to the outside by a small pore known as *incurrent pore or ostium*, but internally it ends blindly.

(b) *Radial canal or excurrent canal.* It is closed externally but opens internally by minute pores or *apopyles* into a central cavity or *cloacal cavity* or *gastral cavity* or *spongocoel*, which cannot be compared in any way with the stomach or intestine of other animals.

(c) *Prospopyle.* It is a smaller canal or passage-way connecting incurrent canal with radial canal.

The incurrent canals are lined by flat squamous cells and their functions are only to form water conduits and to form a smooth and firm surface.

The *excurrent canals* or *radial canals* are lined by *collar cells* opening at the surface and are provided with flagella or whips. The lashing movements of flagellum procure the food particles and push them into the cell-mouth. Thus, this is food capturing arrangement of sponges.

Spongocoel or central cavity is lined by a thin gastric epithelium. It opens to the outside by an aperture, called *osculum.*

I. Ascon type.

It is the simplest type of canal system in which the body has is thin walled (cavity) bilaterally symmetrical and hollow due to the *central cavity.* This cavity is known as the *spongocoel* or *paragastric cavity* that opens to the outside by means of a circular aperture (known as osculum) at the free distal end of the cylinder. Numerous minute pores, the ostia, are also present in the think wall of the cylinder. These minutes pores are regularly disposed intracellular apertures each of which is a canal like structure situated within a tubular porocyte. They extend from the outer surface of the body wall to the spongocoel. The water current reaches the spongocoel after passing through the ostia and goes out through the osculum. The body wall of ascon type of sponges is formed of two layers. The outer layer is called *ectoderm* and the inner layer is known as *endoderm.* The ectoderm is formed of thin and flat *pinacocytes.* The endoderm is formed by the *choanocytes* and lines the spongocoel. Between these two layers is a thin *mesogloea* formed of non-living gelatinous substance. It contains different kinds of *amoebocytes* and *triradiate spicules* formed of calcium carbonate.

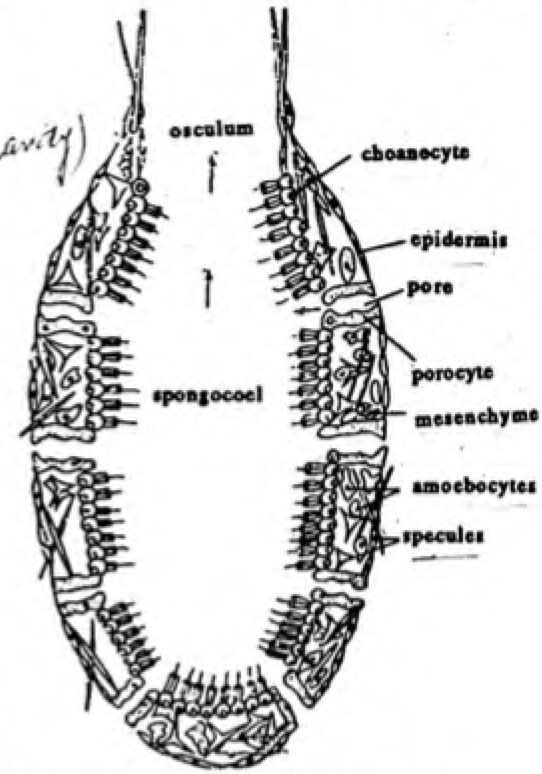


Fig. 19.2 *Asconoid* type of canal system.

The ascon type of canal system is also found in some calcareous sponges such as in the development stages of *Clathrina.* Besides this it is found in *Leucosolenia* and some other simple sponges.

The course of the water current is as follows:

outsider water ⟶ ostium ⟶ prosopyle ⟶ paragastric cavity osculum ⟶ outside.

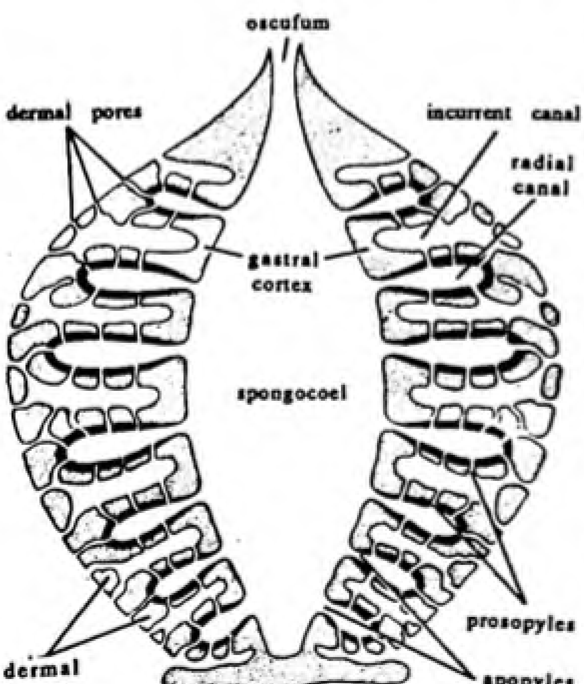


Fig. 19.3 *Syconoid* type of canal system.

II. Sycon type

It is a more complex system as it is folded version of the asconoid body. It is found in *Scypha* and in the embryonic development of *Scypha* clearly shows the asconoid type by the outpushings of the wall of an asconoid sponge at regular intervals into finger-like projections called *radial canals.* At first, these canals are in direct contact with the outside water but in most of the sponges, the walls of the radial canal fuse in such a manner that tubular *incurrent canals* are formed in between. These incurrent canals open to the exterior by dermal ostia or dermal pores. As these incurrent canals represent the outer-surface of asconoid type of surface, they are lined by *epidermis* while the radial canals which represent the outpushings of asconoid spongocoel are lined by *choanocytes.* The interior of the sponge in which raidal canals open is a spaceous spongocoel which is lined by the flat epithelium derived from epidermis. The opening of the raidal canals into spongocoel are termed *internal ostia.* The spongocoal opens to the exterior by a large single osculum. The wall between incurrent and radial canals is pierced by numerous minute pores called *prospopyles.*

The course of water current through the canal system can be represented as follows:

surrounding water $\xrightarrow{\text{dermal ostia}}$ incurrent canals prosopyles $\downarrow$

outside $\xleftarrow{\text{osculum}}$ spongocoel $\xleftarrow{\text{apopyles}}$ radial canals

In the more complicated of syconoid types of canal system, the epidermis and mesenchyme spread over the outer surface forming a thin or thick cortex having cortical spicules. The epidermis is pierced by more definite pores that lead into narrow incurrent canals.

III. Rhagon type

This type of canal system is found in the larva of Demospongiae called *rhagon* which has a broad base and is conical in shape. Due to excessive growth of mesogloea *sub-dermal spaces* are formed in its body wall.

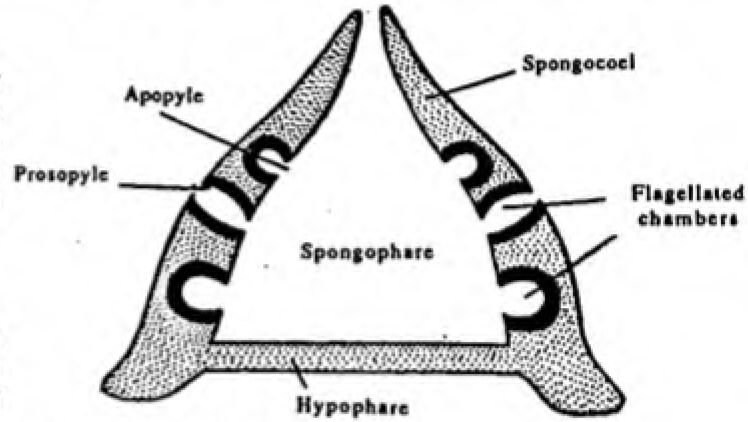


Fig. 19.4 *Rhagon* type canal system.

The ostia open in these spaces which lead into incurrent canals. The incurrent canals open by prosopyles into flagellated canals which are lined with choanocytes. The flagellated canals open by apopyles into excurrent canals which lead into *paragastric cavity.* The paragastic cavity opens to the outside by the osculum which is present at the apex. The incurrent and excurrent canals may be complex and branched in it. The course of water through this system is as follows:

outside water ⟶ ostium ⟶ sub dermal space ⟶ incurrent canals ↘

outside ⟵ excurrent canals ⟵ apopyle ⟵ flagellated canals ⟵ prosopyles

IV. Leuconoid type.

This type of canal system is formed from the rhagon type by the outfolding of the choanocyte layers. In this type, oval or rounded chambers lined by flagellated cells are formed by evagination of the radial canal. The surface is perforated by *dermal pores.* These porces lead into incurrent canals, which are found in mesenchyme. These canals are usually branched. In many cases, dermal pores open into subdermal spaces, which are large and are provided with spicules. Incurrent canals open into small, rounded chambers provided with flagellated cells. The opening of the incurrent canals into the flagellated chambers are called *prosopyles.* The flagellated chambers open into the excurrent canals by small apertures, knowsn as *apopyles.* These excurent canals are united to form large tubes, which open into *spongocoel.* This cavity is largely obliterated. Spongocoel opens to the outside by the *osculum.* Leuconoid type of canal system can be divided into 3 sub-types:-

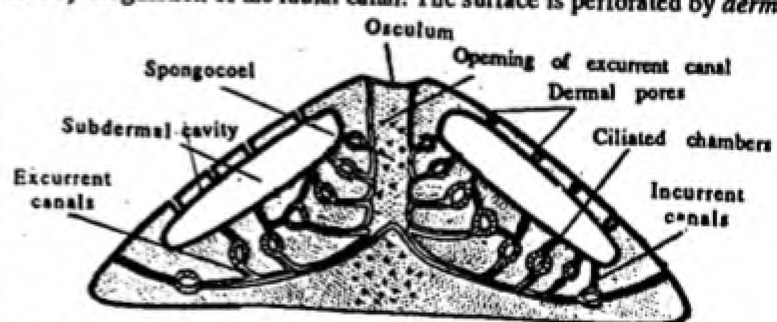


Fig. 19.5 Rhagon type in V.S. of *spongilla.*

(a) ***Eurypylous type.*** In this case the sponge has a flat broad base having an opening at the apex and looks like a pyramid. There are a number of flagellated chambers (*radial canals*) in the upper wall into which the prosopyles open. The lower basal wall is without flagellated chambers and is known as *hypophore* whereas the upper wall with flagellated chambers is called

spongophore. The folded spongophore gives rise to incurrent canals. Due to this folding the flagellated chambers do not open into the gastral cavity but into the diverticula forming the excurrent canals.

(b) *Aphodal type.* In this type of canal system the flagellated chambers do not open into the excurrent canals directly but are removed from the excurrent canals by prolongations of apopyles into small canals called *aphodus* which are lined by the prolongation of the epithelum of excurrent canals into which they open. There is only one prosopyle to each chamber.

(c) *Diplodal type.* In this type incurrent canals do not directly open into flagellated canals but open by narrow canals called *prosodus* which are prolongations of prosopyles. Thus each flagellated chamber has a *prosodus* leading to incurrent canals and an *aphodus* leading from it to exurrent canals.

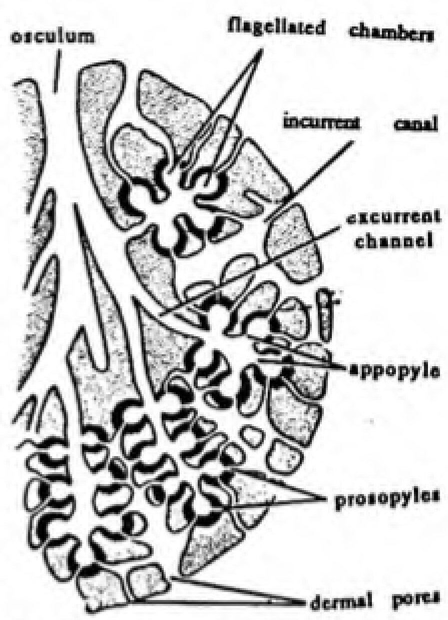


Fig. 19.6 Leuconoid type of canal system with *eurypylas* chambers.

Mechanism of current production

To produce an incurrent or excurrent condition there are two factors which are essential:

(i) For entering water through ostia into the body there must be a pressure within it less than that in the incurrent canals.

(ii) For escaping water through osculum there must be a pressure within chambers higher than that in the excurrent canals.

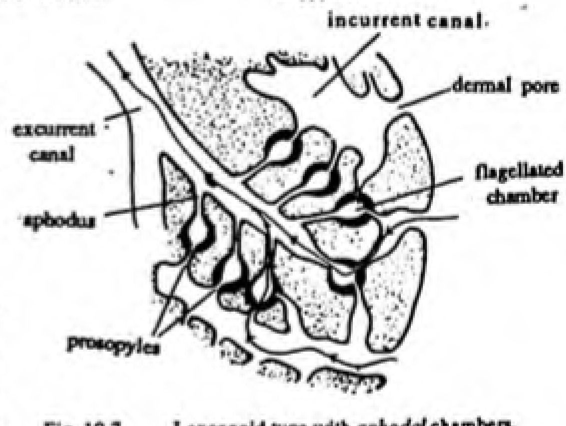


Fig. 19.7 Leuconoid type with *aphodal* chambers.

But as the pressure in the incurrent and excurrent canals is the same, there must be a difference of pressure within the chamber itself and the lower pressure must be towards the periphery. Such a distribution of pressure is set up when each flagellum causes a flow of water towards the centre of the chamber.

Functions of the Canal System.

1. The canal system serves the purpose of *nutrition.* It is regarded as a highway for the food through the body cells in the radial canal with flagella, which capture the food particles. Water-currents are produced by flagella, thus, water flows into the central cavity or spongocoel. Smaller food-particles e.g., diatoms, protozoa and particles of organic debris are ingested into the cell protoplasm and digested. The digestion is *intracellular. Robert Grant* first of all observed the flow of water in the body-wall by adding powdered carmine to the water. Thus, canal system here does the same functions as circulatory system in higher animals.
2. In sponges, as a result of development of elaborate canal system, *massive growth* is found.
3. Streaming currents of water have dissolved air, therefore, gaseous exchange or *respiration* takes place in the cells. Oxygen is taken in by simple process of diffusion and carbon-dioxide is given out. The respiration is also intracellular.
4. The function of the canal system is also *excretory.* Currents of water, which pass outside the osculum remove the carbonic acid and other nitrogenous waste substances, which are the excretory products of the body.

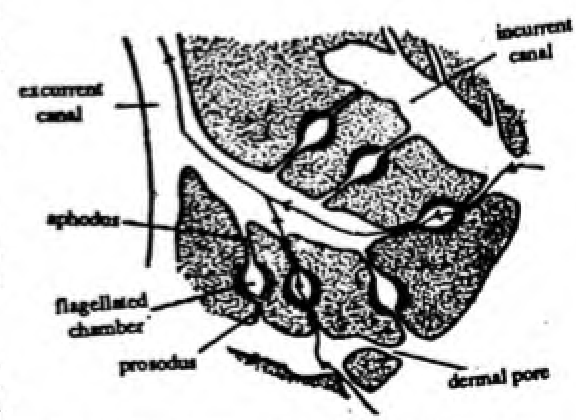


Fig. 19.8 Leuconoid type with *diploidal* chambers.

5. The purpose of the canal system is also to *increase the surface area* of the animal in water. This is a characteristic point by which increase of volume is allowed by keeping the ratio of the surface to the volume.

20

SKELETON IN SPONGES

The skeleton of sponges is formed of spicules or spongin fibres or of both. The spicules are needle-like shiny structures. They have a *central axis* of organic substance around which inorganic substance are accumulated. An *organic sheath* is present outside this layer of inorganic substances. The organic substance of the spicules is in contact at places with the organic matter of the animal. The inorganic substance found in the spicules is either calcium carbonate or silica. The organic axis in siliceous spicules is broad and distinct and is collected around the axis of mineral matter in the form of *concentric lamellae* which serially alternate with each other. In calcareous sponges the calcium carbonate is granular and the organic substances are absent in it.

According to size the larger spicules, constituting the main skeleton, are called *megascleres* and the smaller spicules which occur interstitially are called *microscleres.* Further, spicules may occur in several forms; they may be simple rod-like or may take the form of forks, anchors, shovels, stars, plumes, etc. These forms depend upon the number of axes and rays present.

1. Megascleres.

They are larger spicules and are named by adding *axon* in the number of their axes and *actine* or *actinal* in the number of their rays. They are of the following type:

A. ***Monaxon spicules.*** They are straight or curved, rod-shaped or needle-like spicules which have only one axis. The growth of these spicules can be in one or both the directions of their axis. Thus they are of the following kinds.

(a) *Monactinal monaxon.* When the growth of the spicules take place at one end of the axis, it is called *style.* Its round end is called *strongylote* and pointed end is known as *oxeote.*

(i) *Tylostyle.* Its round end is knob-like.

(ii) *Acanthostyle.* Many minute spines are found on its surface.

(b) *Diactinal monaxon.* When the growth occurs at both the ends of a monaxon spicule it is known as *diactinal monaxon* or simply as *diactine* or *rhabd.*

(i) *Oxeas.* Their both the ends are pointed.

(ii) *Tornotes.* Their ends are like spear-heads.

(iii) *Strongyles.* Their both the ends are round.

(iv) *Tylotes.* Their both the ends are like pin-heads.

B. ***Triaxon spicules.*** These are also called *hexactinal* and occur only in the Hexactinellida. Each consists of 3-axes crossing at right angles. Thus six rays appear which extend from a central point at right angles to each other. This can give many variations by loss or reduction of rays.

C. ***Tetraxon spicules.*** These are also called tetractines and quadriradiates. Each has typically 4 rays, not in the same place. These may be:

(i) *Calthrops.* When 4 rays are more or less equal.

(ii) *Triaenes.* When 1 ray is elongated (rhabdome), bearing 3 smaller rays (cladome). If one smaller ray is lost it becomes diaene.

(iii) *Amphidisc.* When disc occur at both ends of a rhabdome.

A triradiate spicule is the most common spicule of calcareous sponges and results by the loss of the rhabdome of a triaene.

D. Polyaxon spicules. These spicules have several equal rays radiating from a central point.

E. Spheres. These are almost round spicules in which growth takes place around a centre.

Desma is a special kind of megasclere consisting of an ordinary minute monaxon, triradiate, spicule called crepis on which silica is irregularly deposited.

In the beginning silica follows the crepis but later develops elaborate branches and when they are united into a network then it is called *lethisted.*

2. Microscleres.

They are minute spicules which are scattered in the mesenchyme and sometimes are seen projecting in the canals. They are like megascleres in structure but small in size. They are of the following kinds:

(1) Monaxon microscleres.

(2) Polyaxon microscleres.

A. *Monaxon microscleres.* They are only diactinal and found in the form of straight or curved rods. The straight diactinal microscleres are called *Microrhabds.* They are of the following types :

(i) *Micraxeas.* Their both the ends are pointed.

(ii) *Microstrongyles.* Their both the ends are round.

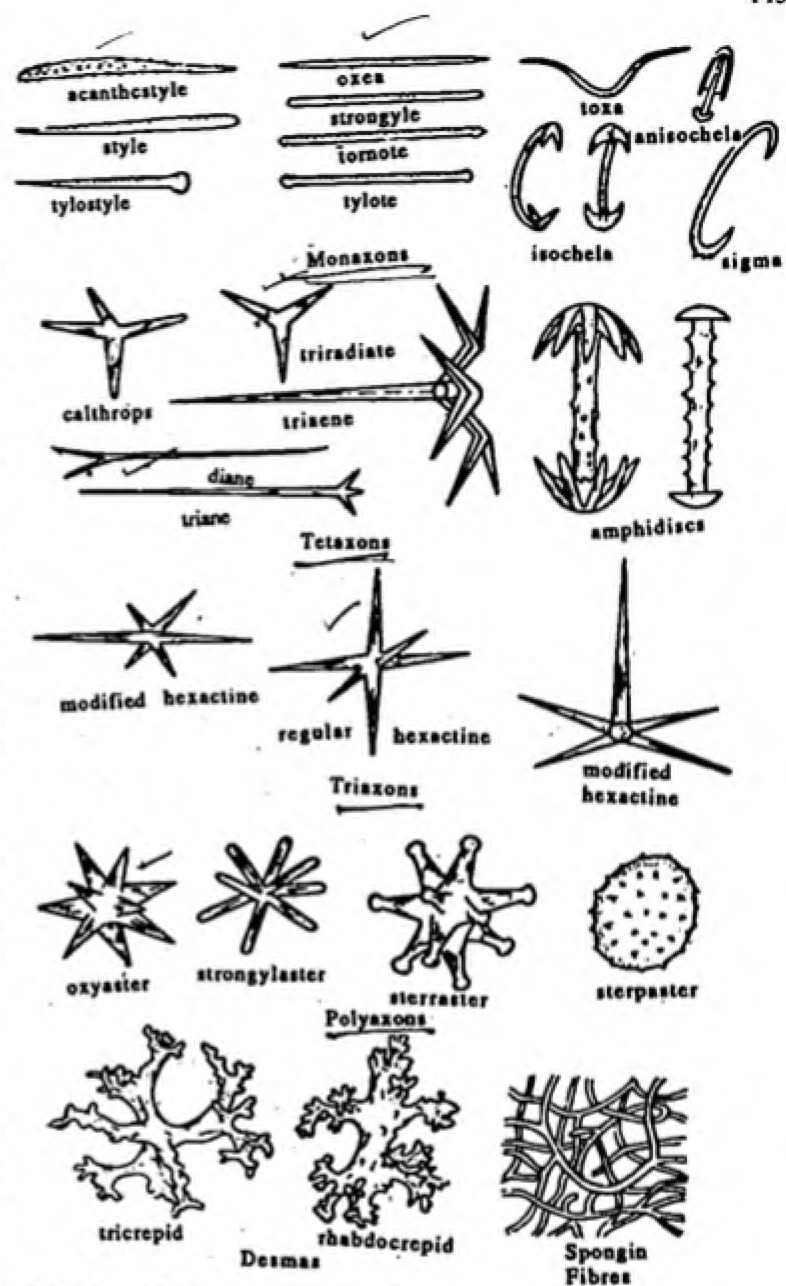


Fig. 20.1 Specules and spongin fibres in *Spongus.*

The curved diactinal microscleres are of the following types:

(a) *Toxas.* They are bow-shaped.

(b) *Sigmas.* They are sigma-shaped.

(c) *Streptasters.* They are spiny spicules.

(d) *Chelas.* Curved hooks or plates are present at their both the ends.

(e) *Sigmaspires*. They are spirally coiled.

B. ***Polyaxon microscleres.*** Many rays radiate in all directions from a central point in these spicules. They are present in much large number than the polyaxon megascleres. Generally, they are called asters.

They are of the following types :

(a) *Large centred forms*

(i) *Spherasters.* The number of rays are definite in them.

(ii) *Sterasters.* Their rays are reduced and are seen only in the form of projections.

(b) *Small centered forms*

(i) *Tylaster.* Knob-like structures are found at their ends.

(ii) *Strongylasters.* The ends of their axes are round.

(iii) *Oxyasters.* The ends of their axes are pointed.

DEVELOPMENT OF SPICULES

The cells that secrete the spicules are known as *scleroblasts.* The spicule may be secreted by a single scleroblast or from more than one mother cell.

1. Monaxon spicules. (i) In a binucleate scleroblast a small deposition of $CaCO_3$ appears. (ii) With development the two nuclei are separated wide apart and scleroblast divides into two cells. (iii) The cell lying towards inner side called *founder* gives shape and length to the spicule and the other cell lying outwards called *thickner* helps to thicken the spicule. (iv) When the spicule is fully formed both the cells migrate in the mesenchyma.

2. Triradiate spicule. (i) To form a triradiate spicule 3-scleroblasts take part. (ii) Each divides and in each pair a small spicule is secreted. (iii) Ultimately these three spicules unite to form a triradiate spicule.

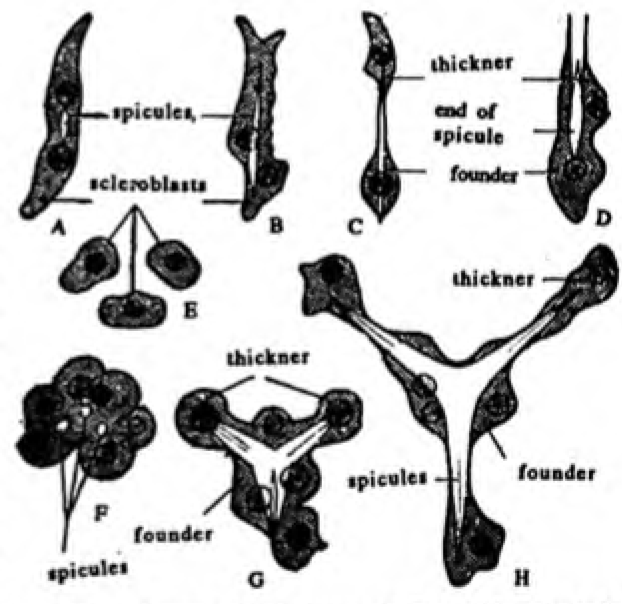


Fig. 20.2 Development of *monaxon* (A-D) and *tri-radiate* (E-H) spicules.

3. Other spicules. Hexactinal spicule is formed by the secretion of silica by a mass of multinucleate mass derived from repeated division of a silicoblast.

SPONGIN

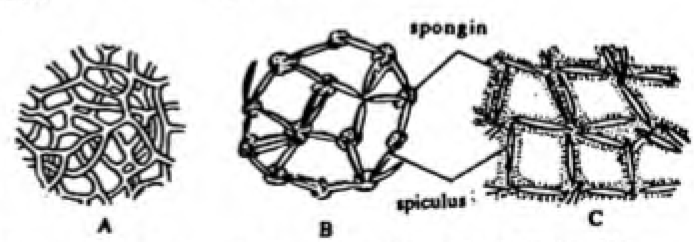


Fig. 20.3 A—Spongin fibres, B and C—Spongin fibres with foreign particles and spicules.

Spongin is an organic, horny, elastic substance, resembling silk in chemical composition. Like nails, hair and feathers, it is a scleroprotein containing sulphur and chemically related to collagen, a horny protein. It is insoluble, chemically inert and resistant to protein-digesting enzymes. Spongin contains a large amount of iodine reaching 8 to 14 percent in certain tropical species of the Spongiidae and Aplysinidae. It is interesting to know that old herb-doctors for centuries used bath-sponge as a cure for crop.

Spongin occurs in various forms in the class Demospongia. It may occur as a cement connecting together the siliceous

archaeocytes is an outlet, which is called *micropyle.* These gemmules are produced by the sponges when they are unable to live due to the excessive cold or drought. The fresh-water sponges from a large number or gemmules in autumn and then disintegrate; gemmules are found in the remnants of the body of sponge or they fall to the bottom. Gemmules can withstand freezing and drying. They are, therefore, generally produced by the sponge in the autimn, when adult sponges die. In India, gemmules are generally found on the approach of summer. On the return of favourable conditions in the spring, gemmules hatch. *Zeuthen* (1939) found that gemmules can hatch at any time at the temperature of 21-33°C. According to *Brien* (1932) hatching takes place when the contained cells of the gemmules stream into the micropyle. The large multinucleate archaeocytes divide into uninucleate ones and into small cells or *histoblasts,* which first of all originate and arrange to form an epidermis, differentiate so as to form *choanocytes, porocytes* and internal linings of spaces. Archaeocytes modified into *scleroblasts* produce spicules and after a week by differentiation and arrangement a new complete sponge is formed, surrounding the empty gemmule shell. In some cases, *forminal tube* is also formed. It is a protrusion of outer membrane in the form of tube. Later on differentiation and arrangement of cells take place.

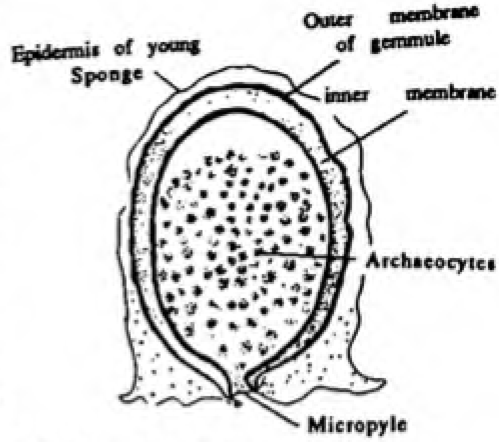


Fig. 21.3 Germinating gemmule of a *sponge.*

(iv) *Formation of Reduction Bodies.* These are formed during unfavourable conditions. It involves masses of many kinds of amoebocytes with epidermal coverings that persist after the disintegration of the parent sponge. These reduction bodies can develop into sponges in favourable conditions. They differ from gemmules in not having an external layer of columnar cells with spicules.

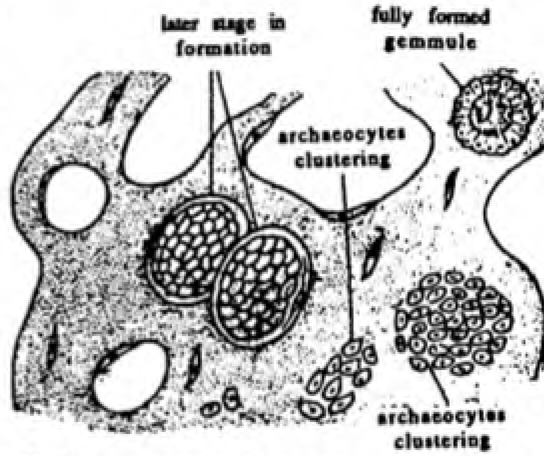


Fig. 21.4 Formation of gemmules in a marine *sponge.*

(v) *Regeneration in Sponges*

All animals, particularly the less specialized ones, can replace their lost or injured parts. The process is known as *regeneration.* It is greater in simple animals and in simple tissues. Thus, epithelial tissues regenerate readily, whereas highly differentiated tissues, such as muscle or nerve tissue, have very limited power of regeneration. The sponges, correlated with their low grade of organization, have a high capacity to regenerate. If an individual is cut into pieces, each piece, however, small it may be, will grow into a complete or full-size sponge if conditions are favourable. The regenerative power of certain sponges is quite noteworthy as demonstrated by *H.V. Wilson* (1907) by a simple experiment. If a sponge is chopped into small pieces, run through a meat grinder and then squeezed through fine silk bolting cloth, its cells are separated from one another. In a suitable medium, some of these disunited cells come together by amoeboid movements and unite to form small aggregates or *spongelets.* In course of several days these reunited masses acquire canals, flagellated chambers and skeleton, thus growing up into new sponges. Cells from different species of sponges may adhere temporarily but later separate, without re-forming a sponge.

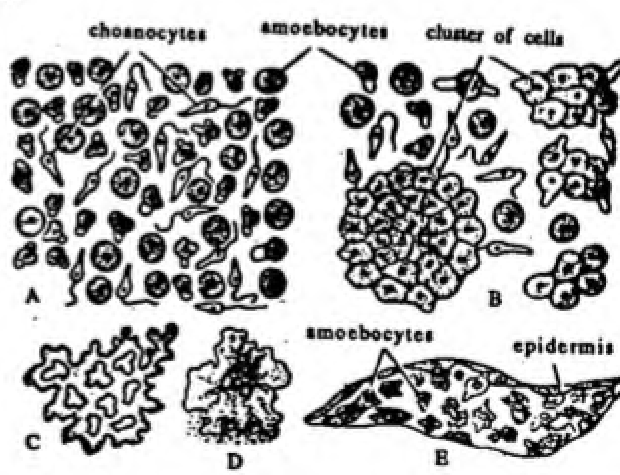


Fig. 21.5 Wilson's experiment on regeneration in *sponges.* A—Cells of *Microciona* separated by squeezing living sponge through bolting cloth. B—Cells aggregating in to small masses. C—A reticulate reunion mass. D—Later stage forming a young sponge or spongelet. E—Section through a stage like D.

(B) Sexual Reproduction. Sponges reproduce by sexual reproduction: by formation of ova and spermatozoa. Majority of sponges are hermaphrodie (Gr. *Hermes,* aphrodite) *i.e.,* an individual possesses both male and female reproductive organs

but some are dioecious (Gr. *di*, twice; *oikos*, house) *i.e.*, having the male and female reproductive organs in separate individuals. In bisexual or hermaphorodite or monoecious forms, germ-cells of the male mature before those of the female, thus, producing sperms and ova at different periods. Eggs usually develop in the basal part of the sponge, while the sperms are formed on the apex.

Sexual reproduction in sponges, which live in shallow water, takes place at certain seasons of the year, whereas deep-sea sponges reproduce throughout the year. Sex-cells are produced from the archaeocytes but, according to some authors, sex cells originate from choanocytes. The ovum is formed by the enlarging of *amoebocyte* or *amoeboid* cell. It has a large nucleus and a distinct nucleolus. It grows and acquires food material. When full size is reached, oogonium or egg mother cell undergoes maturation divisions. In some sponges the sperm mother cell or spermatogonium is the enlarged amoebocyte covered by one or more flattened cover-cells, thus, forming spermatocyst. The spermatogonium which is in the spermatocyst, divides twice or thrice into spermatogonium, which produce sperms. Spherical bunches of minute spermatozoa are formed by repeated divisions. *Gatenby* described that the choanocytes divide into spermatozoa. These spermatozoa have rounded heads and vibratile tails for rapid movement in water.

Fertilization: Sperms of one sponge is carried by water current outside the body and enters into another sponge of the same species with incurrent water. This directly fuses with the ovum or get attached with a choanocyte lying near the ovum. The choanocyte with the sperm fuses with the ovum and set free the sperm which then fuses with ovum. Thus in sponge cross-fertilization occurs which is internal.

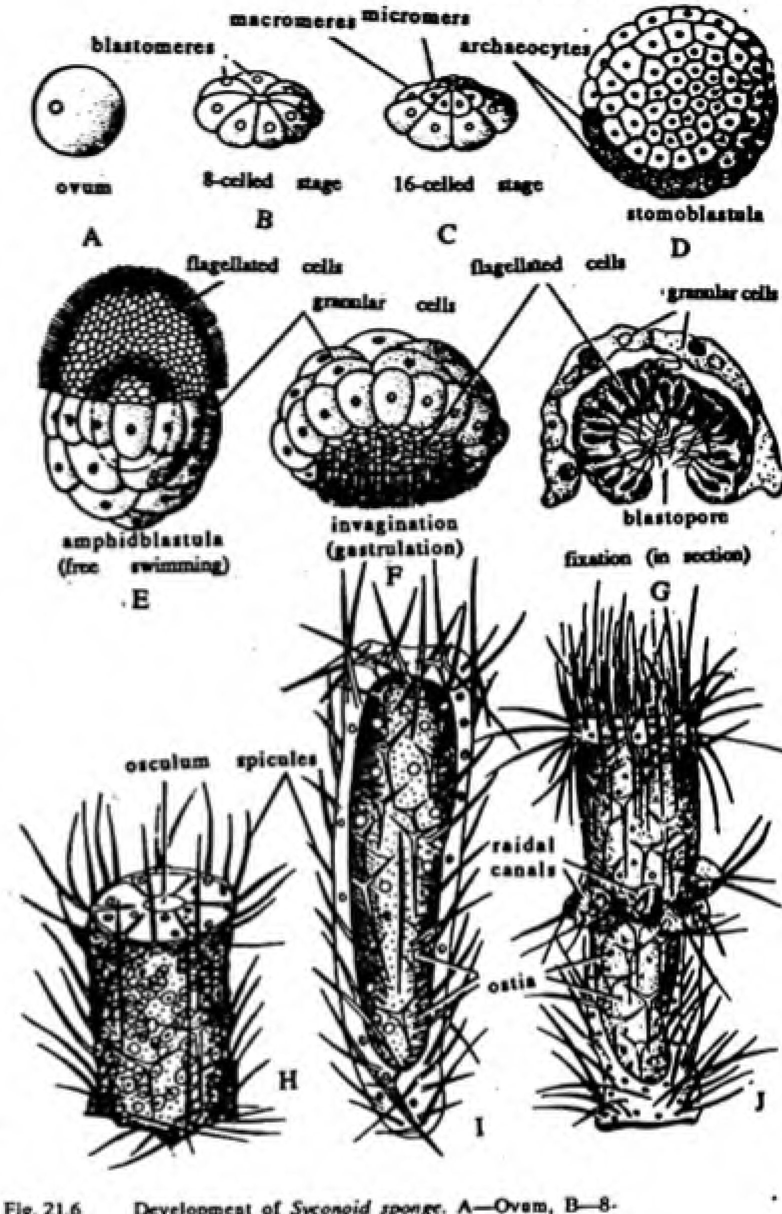


Fig. 21.6 Development of *Syconoid sponge*. A—Ovum, B—8-celled stage, C—16-celled stage, D—Blastula, E—Amphiblastula, F—Beginning of invagination, G—Gastrula showing fixation (in section), H—Young sponge, I—Asconoid (olynthus) stage, J—Syconoid stage.

Development

The fertilized ovum is called *zygote* which develops in the parental mesenchyme for sometime and gets covered by capsule.

(i) *Cleavage or segmentation*. The division of zygote is holoblastic (complete) and equal or unequal. Ultimately there appears an embryo in which 8 cells attached with parental tissue form the future *pinacoderm* and the other cells form the *choanoderm*. A cavity appears between these two and the embryo is now called *blastula* which leaves the parent body and form a free-swimming larva.

(ii) *Larval forms*. In all known case, during development of embryo a free-swimming ciliated larva appears but the form assumed by the larva differs in different sponges.

In case of *Clathrina* and *Leucosolenia* oval blastula changes to *coeloblastula*. This has a single layer of cells, all alike in kind - elongated, columnar and flagellated. At one pole is seen a pair of cells which are of a different character being large, rounded non-flagellated and granular which form *archaeocytes*. This changes into *stereogastrula larva* which is called *parenchymula larva*. The changes are -

(a) Some of the flagellated cells withdrawn their flagella and pass as amoeboid cells into the internal cavity.

(b) Archaeocytes also sink into the internal cavity.

(c) Soon these cells fill up the greater part of the internal cavity and the larva is now called *parenchymula larva*.

In this condition the larva attaches itself to the substratum and develops into adult form. Most of the amoeboid cells now migrate to the outside to form the dermal epithelium. The flagellated cells become internal and form the choanocytes. Ostia, osculum, spicules and spongocoel are formed and it attains the young stage.

In some other sponges like *Sycon* and *Grantia* the zygote undergoes holoblastic cleavage and at 16-celled stage gets fixed with the maternal choanocytes represent future epidermis and other 8-cells (micromeres) are future choanocytes which divide repeatedly and acquire flagella on inner side facing blastocoel. The megameres or future epidermal cells are large and round cells at the centre of which arises a mouth. This stage of the embryo is called *stomoblastula*.

The next process is *inversion* of stomoblastula resulting in a typical larva called *amphiblastula*. During inversion the embryo turns completely inside out through the mouth. Due to this the flagellated cells form the anterior half and the posterior half is formed by large non-flagellated granular cells.

The amphiblastula now passes through the radial canal to the outside and swims forward keeping the flagellated end at the anterior. During this time gastrulation occurs by *invagination* of the flagellated part into the non-flagellated macromere cells.

The gastrula then attaches itself to some substratum, it develops the central spongocoel, ostia all over its body and the large opening osculum at the free-end. It now looks like young sponge and is called *olynthus* or asconoid stage. Slowly radial canals develop and it is changed to a syconoid from or adult stage.

22

ECONOMIC IMPORTANCE OF SPONGES

Sponges are of great economic importance, they are useful as well as harmful to mankind.

1. Useful sponges to man. The flexible and highly absorbent spongin skeleton of marine sponge, *Euspongia* and *Hippospongia*, forms, after the removal of living parts, the bath sponge of commerce. The later is used for bathing, washing window pans and automobiles, mopping, ceramic work, and many more similar purposes, Today, cloth and artificial sponges of rubber or cellulose have greatly replaced the natural sponges for many purposes. Even then they are put to a wider variety of uses.

2. Sponges for Decoration and Presentation. Many people use certain glassy, transparent sponges (*Hyalonema*) for decoration purposes. Venus's-flower-basket is a beautiful sponge. It (*Euplectella*) is used for decoration and for presentation to newly wed couples symbolising a happy long married life like a pair of crustaceans which get enclosed within the body of this sponge for ever.

3. Sponges as food. Although the sponges are not eaten by other animals like fishes etc. due to their disagreeable taste and unpleasant odour, but Nudibranch molluses make a regular diet of sponges. Some parasitic crustaceans also feed on their tissues. Thus sponges have a food value to these animals.

4. Sponge fishing or sponge industry. Although synthetic sponges have become widely used, and largely replaced natural sponges yet natural sponges still have a great market, therefore, sponge industry is of great economic value. Since the days of Greece, the fibrous skeleton of bath sponge, *Euspongia* is used for washing and mopping. The water holding capacity of the skeleton is due to capillary forces in the fine spaces of irregular spongin net work. The best and principal supplies of sponges occur on rocky bottoms in warm shallow water of the Mediterranean sea and the Gulf of Mexico, Tarpon springs, Florida of United States the best commercial sponge fishing centre of U.S.A. where more than a million of dollars worth of sponges have been collected in a year. However, fungus infection reduce the total yield.

Sponges are collected by several methods, by drag hooks, by trawlers and by divers. In deeper waters, they are gathered by dredging or trawling or more commonly by divers, either with or without a diving suit known as skin divers. In shallow waters, sponges are gathered by the help of long handled hooks operated by two men while one man rows, the other looks at the bottom of the ocean through a glass-bottomed bucket. The marketable variety is taken out with a two pronged hook, fastened to a long pole.

Living sponge is black in colour, smooth and slimy mass having a leathery covering. In the inside, it resembles to a piece of raw beef liver, both in consistency and colour. After cleaning so as to remove dirt, sponges are hung from the riggs of the boat and their protoplasm is allowed to decay. Later, they are well washed, beaten, bounded with a wooden mallet so as to break up any solid material such as invertebrate shell and ultimately by dried in sun, cleaned sponges are cut or trimmed, sometimes bleached, graded, sorted and then auctioned. Sponges can be easily pressed for shipping due to their great elasticity. For sponge culture, the cut pieces are about 8 cu inches are fastened to slabs or concrete or other support where water current provide abundant food and oxygen.

5. Sponges and their association with other animals. Some sponges show commensalism as several crustaceans, worms, molluses and fishes inhibit and live in the internal cavities of sponges for protection against enemies. They also get a good supply

of food in the circulating water. The spongocoel of *Hyalonema* and *Euplactella* is occupied by a pair of shrimp of genus *Spongicola*. It is the example of commensalism. The shrimps enter the spongocoel in small and young condition as they grow inside their exit become impossible through the sieve plate covering the osculum.

Another example is that of a small family of crabs (*Hyas, Dromia* etc.) in sponges. The crabs cover themselves with bits of sponges, algae hyroids etc. with the help of a sticky secretion. The implanted sponge grow and moulds itself. This covering act as caumoflage but also protects the crab from its predators.

6. Harmful sponges. Sponges are not only useful to mankind but there are some sponges which are harmful to us. The boring sponge *Cliona* bore the shells of the oysters and barnacles and break them into pieces resulting their death. Some sponges produce poisonous secretions and when touched the skin is pricked by the poisonous spicules producing itching of the skin.

23

PHYLUM-COELENTERATA

Coelenterate was formerly regarded as Phylum divided into two subphyla: Subphylum Cnidaria including *Hydra, Obelia, Aurelia,* Corals and Sea-anemones, and Subphylum Acnidaria including Ctenophora (*Pleurobranchia, Beroe* etc.) But during recent years *Hyman* (1940), *Barnes* (1980) and others regard the Coelenterata (Cnidaria) and Acnidaria as two distinct phyla on the basis of a number of dissimilarities between the two.

The coelenterates are regarded as primitive Metazoa in which the cells are organized to reach the tissue stage. In fact, all the basic types of tissues of higher animals are found in them viz. epithelial tissues for covering the body, muscular tissue for support, nervous tissue for conduction of stimuli and reproductive tissue for the reproduction.

Derivation of Name

All the coelenterates possess a single large cavity, the *gastrovascular cavity*. This cavity performs the function of digestion and distribution of digested food materials. It has only one exit, the mouth. Term Coelenterata was first used by *Leuckart* (1847) for those animals in which the enteric carity form the body cavity. The name Coelenterata has been derived from two Greek words, *Koilos* = hollow, *enteron* = intestine. Thus the name of this phylum literally means hollow intestine but hollow bodies is considered more appropriate because actual intestine is not found in coelenterates.

General Characters

1. They are simplest Metazoa showing the cell-tissue grade of organization.
2. All the members of this phylum are aquatic, most of whom are marine others are found in fresh water, none is parasitic.
3. They are either colonial or solitary. They are sedentary or free-swimming.
4. Symmetry is usually *radial* about an oral-aboral axis. In some forms, however, it is *biradial*.
5. Head and segmentation is absent.
6. They exhabit two different body forms, the *medusa* which is adopted for a pelagic existence and the *polyp*, which is adapted for an attachment benthic existence. Colonial forms have evolved in many polypoid forms.
7. One or more whorls of tentacles encircling the mouth at one end of the body. These are used for food-capturing, ingestion and defence.
8. The soft and delicate body may be supported by horny or calcareous exoskeleton or endoskeleton.
9. The body-wall is composed of two layers of cells (*diploblastic*), the outer epidermis and inner endodermis or gastrodermis, and an intervening *mesogloea*. The mesogloea may be thin or thick, cellular or acellular and is secreted by the epidermis and endodermis.
10. There are special stinging cells, the *cnidoblasts* which produce in them the peculiar *nematocysts* the organelles of offense and defence. About 17 types of such nematocysts have been identified.
11. Characteristic undifferentiated *interstitial cells* are found among the epiderminal cells.
12. They are primitive in their lack of organs, their lack of fully differentiated epithelial and muscle cells. A muscular system consisting of contractile processes of epithelial cells.

13. Only one cavity lined with endodermal cells, is found in the body called *gastrovascular cavity*. It performs the function of digestion of food and distribution of digested food. It opens out through the mouth which opens into *stomodaeum.*
14. Mouth serves for ingestion of food as well as egestion of undigested food.
15. Digestion intracellular and intercellular.
16. There is no separate body cavity or coelom because coelom separate from alimentary canal, as found in higher Metazoa, is absent. Thus these are acoleomate.
17. There is no special organelles for respiration, excretion and circulation. Respiration and excretion through general body surface by diffusion.
18. Nervous system is primitive consisting of neurons. The neurons are usually arranged as a nerve-net at the base of epidermal and gastrodermal layers, and the impulse transmission tends to be radiating.
19. Sense organs may be simple or complex. In some eye-spots or statocysts are found.
20. Asexual and sexual both types of reproduction is seen. Asexual reproduction by budding. In sexual reproduction gametes are formed in gonads. Gonads are simple without any duct.
21. Cleavage holoblastic. Development indirect with a ciliated free-swimming stereogastrula, called the *planula larva.*
22. The life-history usually exhibits *metagenesis* in which free swimming sexual generation (medusa) and sedentary asexual generation (polyp) alternate with each other.

CLASSIFICATION

Phylum-Coelenterata includes about 10,000 known species. About 5000 are known only as fossils. They are grouped into three classes:

Class — I Hydrozoa.

Class — II Scyphozoa.

Class — III Anthozoa.

Class - I - Hydrozoa

(Hydrozoa - Gr. *Hydro* = Water; *zoon* = animal).

1. Mostly colonial and marine, a few solitary and fresh-water; sessile or free-living.
2. They are *tetramerous symmetrical* or *polymerous symmetrical.*
3. Members of this class are medusoid or polypoid or show both forms in their life-cycle.
4. Mesoglea is acellular.
5. Nematocysts occur only in the epidermis.
6. Gametes develop in the epidermis.
7. Hydromedusae are usually small and planktonic.
8. The asexual polypoid form arises from sexual medusoid form and the latter arises from the former, thus exhibiting metagenesis in the life-cycle of some hydrozoa e.g., *Obelia.*
9. Naked solitary species e.g., hydras probably stem from early polypoid forms which were not colonial.
10. Associated with colonial organization have been the evolution of a skeleton (support) and division of labour (Polymorphism).
11. Zygote undergoes complete cleavage and a hollow blastula is formed which changes into a solid stereogastrula whose ectodermal cells acquire cilia and then this stereogastrula changes into free-swimming planula. Planula settles down, attaches

by its anterior end to a substratum and by budding forms the branched colonial polypoid stage.

The class Hydrozoa is divided into five orders:

Order (i) Hydroida

1. Solitary or colonial.
2. The polyps are more developed.
3. Medusoid stage present or absent.
4. Sense organs of medusae are exclusively ectodermal.

It is divided in following sub-orders:

Suborder (a) Anthomedusae or Athecata

1. Skeletal covering, when present, does not surround hydrotheca. Freshwater or marine.
2. Polyps are naked.
3. Medusae are bud or bell-shaped. The gonads are situated on the manubrium. Statocysts absent.

Examples: *Hydra, Protohydra, Bougainvillea, Tubularia, Hydractinia* etc.

Suborder (b) Leptomedusae or Thecata

1. Usually marine.
2. Hydranth surrounded by theca.
3. Medusa flatenned, bowl shaped. Gonads are present on the radial canals. Eyespot and statocysts are present.

Examples: *Obelia, Sertularia, Plumularia, Aglaophania* etc.

Suborder (c) Limnomedusae

1. Polypoid stage without perisarcal skeleton.
2. Some only with medusoid stage.

Example : *Graspeda custa.*

Order (ii) Hydrocorallina

1. Polypoid generation forming a coloney which secretes a massive calcareous skeleton having minute pores at the surface through which the polyps protrude.
2. Polyps dimorphic, nutritive gastrozooids and dactylozooids.

Suborder (a) Milliporina

1. Skeleton covered by only a thin epidermal layer.
2. Dectylozooids are long, hollow and with tentacles.
3. Mature medusae lead an independent life.

Example: *Millipora.*

Suborder (b) Stylasterina

1. Dactylozooids are small, solid and without tentacles.
2. Polyps are symmetrically arranged.

3. Medusa develop in special spore sac and never free.

   Example: *Stylaster*

Order (iii) Trachylina

1. *Medusoid* forms only, polypoid forms are absent or reduced.
2. Medusa with a velum beneath the margin of the bell and the tentacles inserted above the margin.
3. Statocyst and tentaculocysts present.
4. The planula give rise to the adult through an *actinula larva*.

   Order Trachylina is divided into two suborders:

Suborder (a) Trachymedusae

1. Sense tentacles in pits or vesicles.
2. Gonads on radial canals.
3. Margins of bell are smooth.

   Examples: *Carmarina, Petasus.*

Suborder (b) Norcomedusae

1. Sense tentacles not enclosed.
2. Gonads in the floor of stomach.
3. Margins of bell scalloped by tentacle bases.

   Examples: *Cunina, Polycolpa.*

Order (iv) Siphonophora

1. Free floating or free swimming colonies, showing maximum polymorphism.
2. Individuals attached to a linear stem or a circular disc.
3. A *pneumatophore* or float filled with air is present at the top in some cases.
4. Oral tentacles absent.
5. Nematocysts large and powerful.
6. Medusae incomplete, never free.

   This order is divided into two suborders:

Suborder (a) Calycophora

1. Pneumatophore is absent.
2. One or more swimming zooids are present in the upper part of the coloney.

   Examples: *Abyla, Diphyses, Praya.*

Suborder (b) Physophorida

1. A large pneumatophore is present at the upper end of the colony.
2. Zooids are polypoid and medusoid.

Examples: *Physalia, Halistemma, Velella, Porpita.*

Class-II Scyphozoa

1. Class Scyphozoa include large jelly fishes.
2. Polyp stage is usually reduced or absent.
3. Medusa are large, umbrella-shaped without velum. Perisarc is absent.
4. The sense organs are in the form of hollow tentaculocysts having statolith.
5. The gastral tentacles are endodermal.
6. Mesogloea enlarged and usually cellular.
7. The gonads are endodermal and release the gametes in stomach.
8. Stomadaeum is absent in the gastro-vascular system but gastric tentacles are present and the cavity is divided into interradial pockets by four ridges or speta.
9. Alternation of generation is seen in some.
10. They are exclusively marine.

The class is divided into 5 orders.

Order (i) Lucernarida

1. Mostly found in cold littoral waters.
2. Sessile and sedentary, attached to the substratum by the aboral stalk.
3. Body is goblet or trumpet shaped.
4. Mouth is four cornered with small oral lobes and a short manubrium.
5. Tentacles are present in some, they are per-radial and inter-radial.
6. The umbrella is cup-shaped.
7. Gonads are long band-shaped lying on faces of septa.
8. Larva is planula with cilia.

Examples: *Lucernaria, Haliclystus.*

Order (ii) Coronatae

1. Free swimming forms living in deep sea.
2. Body conical or dome-shaped divided into an upper cone and lower crown by a coronary groove.
3. Solid tentacles are per-radial and ad-radial, 4 inter-radial *rhopalina* present.
4. Four to sixteen tentaculocysts.

Examples: *Pericolpa, Atolla.*

Order (iii) Cubomedusae

1. Free-swimming found in warm and shallow waters.
2. The umbrella is four-sided and cup-shaped.
3. Four hollow inter-radial tentacles and four per-radial tentaculocysts are present. Each tentaculocyst with one or more ocelli and a lithocyst.

4. A true velum is absent.
5. Gonads are leaf-like and there is no alternation of generation in life-cycle.

   Examples: *Chiropsalmus, Tamoya.*

Order (iv) Semaeostomae

1. Common free-swimming animals found all over the world.
2. The umbrella is disc-like.
3. Mouth surrounded by four oral arms.
4. Eight or more tentaculocysts are present.
5. Gastric pouches and septa are absent.

   Examples: *Aurelia, Cyanea.*

Order (v) Rhizostomae

1. Free-swimming forms found in shallow water of tropical and subtropical oceans.
2. The mouth is obliterated by the growth across it of 8 very large and branched oral arms.
3. The stomach is continued into the canals opening by funnel shaped apertures on the edges of the arms.
4. Umbrella is saucer or bowl-shaped.
5. Marginal tentacles absent.
6. Tentaculocysts are 8 or more in number.

   Examples: *Rhizostoma, Cassiopea, Pilema*

Class-III Anthozoa or Actinoza

1. Exist only in the polyp form, no medusa stage.
2. Differ from hydrozoan and scyphozoan polyp in possessing a stomodaeum, paired mesenteries (their free ends bear coiled mesenteric filaments like the gastric filaments of scyphozoan but are partially ectodermal in origin).
3. Body wall consists of ectoderm and endodem separated by a strong mesogloea having fibres and cells.
4. Stomodaeum consists of the same layers reversed i.e., its lining membrane is ectodermal. The mesenteries are formed by a double layer of endoderm with a supporting plate of mesogloea.
5. More complex nematocysts than in Hydrozoa and Scyphozoa are found in the tentacles, body-wall, stomodaeum and mesenteric filaments.
6. Muscular system is well-developed containing both ectodermal and endodermal fibres and endodermal muscule processes.
7. Nervous system is a typical nerve net.
8. Gonads develop in the mesenteries, sex cells are located in the endoderm, and sperm and ova are discharged into the coelenteron.
9. The zygote develops into a planula which after swimming freely for sometime settles down and metamorphoses into the adult form.
10. Except in one doubtful instance there is no alternation of generations.

    The class-Anthozoa is divided into 2 sub-classes:

SUB CLASS-1. HEXACORALLINA OR ZOANTHARIA

1. Solitary or colonial marine forms.
2. Tentacles and mesenteries very numerous, arranged in multiple of six.
3. Tentacles are simple, unbranched, hollow cones.
4. Two siphonoglyphs are present and two pairs of directive mesenteries; the remaining mesenteries are generally arranged in couples with the longitudinal muscles of each couple facing one another.

Order (i) Actiniaria

1. The animals are commonly called sea-anemones. They are solitary or colonial, brightly coloured.
2. Tentacles and mesenteries are numerous.
3. Skeleton is absent.
4. One or more siphonoglyphs.

   Examples: *Metridium, Adamsia, Edwarsia.*

Order (ii) Madreporaria

1. The animals are usually colonial.
2. Skeleton is external and calcareous.
3. Siphonoglyph is absent.
4. Polyps are very small.
5. These are stony corals.

   Examples: *Corallium, Madrepora, Fungia, Meandra, Favia.*

1. Mostly colonial and some are solitary forms.
2. The tentacles are umbranched.
3. The skeleton is usually of a calcareous nature but in few cases there is a horny axial skeleton.
4. Polyps are small and often united by basal stolons.
5. Mesentries paired. Each pair with a complete and an incomplete mesentery.
6. They have single siphonoglyph.

   Example: *Zoanthus.*

Order (iv) Antipatharia

1. These are compound tree-like animals.
2. The tentacles and mesenteries are comparatively few (6-24) in number.
3. The skeleton is present in the form of a branched chitinoid axis.
4. Two siphonoglyphs.

   Example: *Antipathes.*

Order (v) Cerianthcaria

1. The individuals are long and solitary.

2. Skeleton is absent.
3. The mesenteries are incomplete.
4. Numerous, simple tentacles are arranged in two wholrs-oral and marginal.
5. There is a single dorsal siphonoglyph.

   Example: *Cerianthus, Pachycerianthus.*

SUBCLASS-2 OCTOCORALLINA

1. Colonial marine forms.
2. Only polyps no medusae.
3. Tentacles and mesenteries always eight in number.
4. The tentacles pinnate; i.e., produced into symmetrical branchlets.
5. Never more than one siphonoglyph, which is ventral in position, i.e., faces the proximal end of the colony.
6. The arrangement of mesenteries is not always in couples (or pairs) and all their longitudinal muscles are directed ventrally i.e., towards the same side as the siphonoglyph.

   This subclass is divided into following orders:

Order (i) Stolonifera

1. Found in shellow waters.
2. Polyps arising form a creeping stolon.
3. Skeleton either absent or of calcareous tubes or separate calcareous spicules.
4. Found on coral-reefs in old and new world.

   Examples: *Tubipora, Clavularia.*

Order (ii) Telestacea

1. Coloney formed of simple or branched stems arising from a creeping base.
2. Skeleton of calcareous spicules.

   Example: *Telesto.*

Order (iii) Alcyonacea

1. The skeleton usually consists of calcareous spicules or the spicules become aggregated so as to form a coherent skeleton.
2. Some forms may be dimorphic.
3. Body is branched with a central axis.
4. Polyps embedded in fleshy coenochyme.

   Examples: *Alcyonium, Gersemia.*

Order (iv) Coenothecalia

1. Blue or brown corals found on coral reefs in the Indo-Pacific waters.
2. Skeleton massive, calcareous and blue-green from iron salts.

   Example: *Heliopora.*

Order (v) Gorgonacea

1. The individuals are compound tree-like.
2. Skeleton is calcareous or horny.
3. Spicules are present in mesogloea.
4. Siphonoglyph is absent.
5. A central skeletal axis composed of a horn-like substance, the gorgonin.

   Examples: *Gorgonia, Corallium.*

Order (vi) Pennatulacea

1. The coloney is usually elongated.
2. One end of the coloney remains embedded in the mud at the sea-bottom while other end bears the polyps.
3. The rachis is the axial polyp bearing numerous dimorphic polyps laterally.
4. The skeleton is calcareous or horney.

   Examples: *Pennatula, Renilla, Pteroides*

SERTULARIA

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Hydroidea
Suborder	-	Leptomedusae
Genus	-	*Sertularia*

1. It is a small branching coloney occurs in shallow marine water on submerged objects or rocks.
2. Hydrotheca sessile i.e., not stalked, with *opercula* in pairs along the stem being exactly opposite to each other.

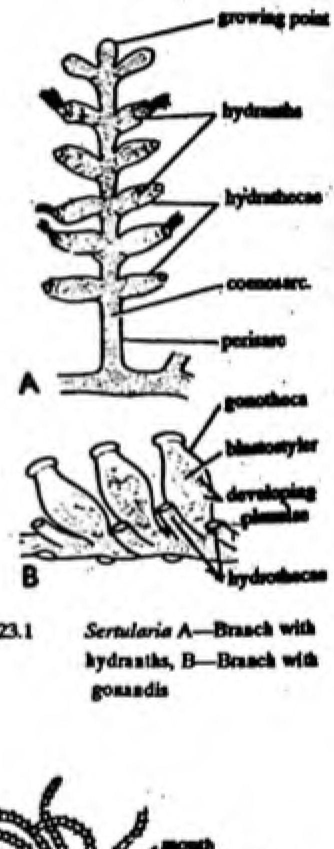


Fig. 23.1 *Sertularia* A—Branch with hydraths, B—Branch with gonandis

3. Hydrothecae are large, polyps retract within themselves.
4. *Gonangia* are of simple form, much larger than hydrothecae, a few in a colony and present only in a certain period of three year.
5. Blastostyles produce planulae and no free medusae.

PLUMULARIA

The classification is the same as that of *Sertularia.*

1. It is a feather - like colony occurs in shallow marine water attached to some substratum.
2. The plume-like colony comes out from creeping hydrorhiza.
3. A series of hydrotheca are found on one side of the branches of the colony.

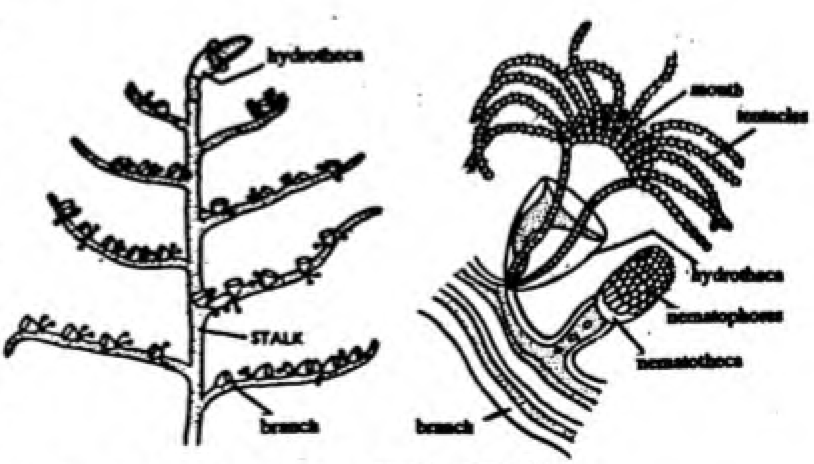


Fig. 23.2 *Plumularia.* A—Coloney, B—Magnified polyp

4. Hydrotheca are small and without stalk and the polyps can be partly retracted within them.
5. Special mouthless polyps known as nematophores are found which have long amoeboid projections.
6. The gonangia are long and superficially resembling the spadix inflorescence.

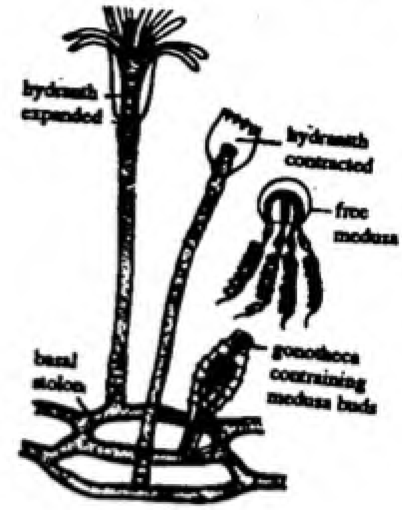


Fig. 23.3 *Campanularia*

CAMPANULARIA

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Hydroidea
Suborder	-	Leptomedusae
Genus	-	*Campanularia*

1. It is a simple branched coloney found attached to submerged marine objects in shallow water.
2. Hydrothecae, enclosing polyps, are bell-shaped usually stalked, without operculum and with or without marginal teeth.
3. Annulated stem at the base of the branch.
4. *Blastostyle* produces *planulae* and not medusae.
5. *Gonangium* long and slender.
6. Hypostome of hydranth or polyp trumpet - shaped surrounded by tentacles.

HYDRACTINIA

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Hydroidea
Suborder	-	Anthomedusae
Genus	-	*Hydractinia*

1. It is a small, marine hydroid found in shallow water attached to stones, sea-weeds and shells.
2. It is commonly found on Atlantic coast, U.S.A., Europe and also found in Sanjuan Island.
3. Zooids are of four types (a) *Gastrozooid* (feeding polyp), *gonozooid* (reproductive zooid), *dactylozooid* (protective zooid) and *tentaculozooid* (sensory polyp).
4. The hydranths are simply mounthless and are called as dactylozooids.
5. The dectylozooids have very short tentacles abundantly supplied with nematocysts.
6. The dactylozooids are capable of very active movements.
7. With the help of massive coenosarc consisting of a number of branches, *Hydractinia* form a firm brownish crust on the surfaces of dead gatropod shells inhabited by hermit-crabs.
8. The association between *Hydractinia* and hermit carbs is called as ***commensalism***.

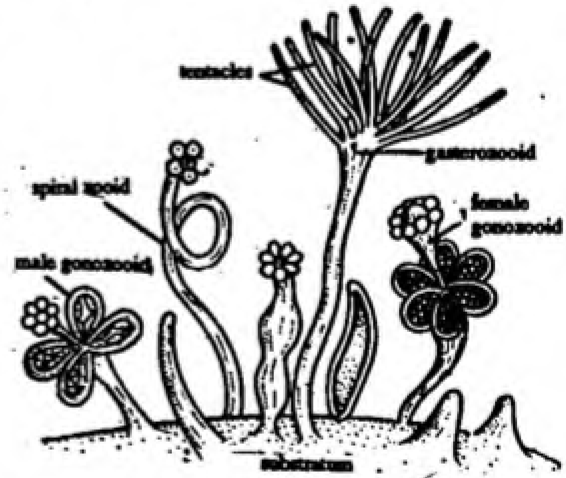


Fig. 23.4 *Hydractinia*

9. The hydroid feeds upon minute fragments of the hermitcrab's food and the hermit-crab is protected from its enemies by the presence of the inedible stinging hydroid.

CERATELLA

Classification is the same as that of *Hydractina.*

1. It is a colonial, sedentary hydroid coelenterate.
2. It is tree-like highly branched animal.
3. It consists of a branching axis composed of many intertwisting and anastomosing tubes.
4. Hydrotheca covers polyp while gonotheca covers medusa.
5. The zooids have scattered capitate tentacles.
6. The medusae bear gonads on the manubrium and devoid of lithocytes.
7. Eye spots are present.

Fig. 23.5 *Ceratella*

BOUGAINVILLEA

The classification is the same as that of *Hydractinia.*

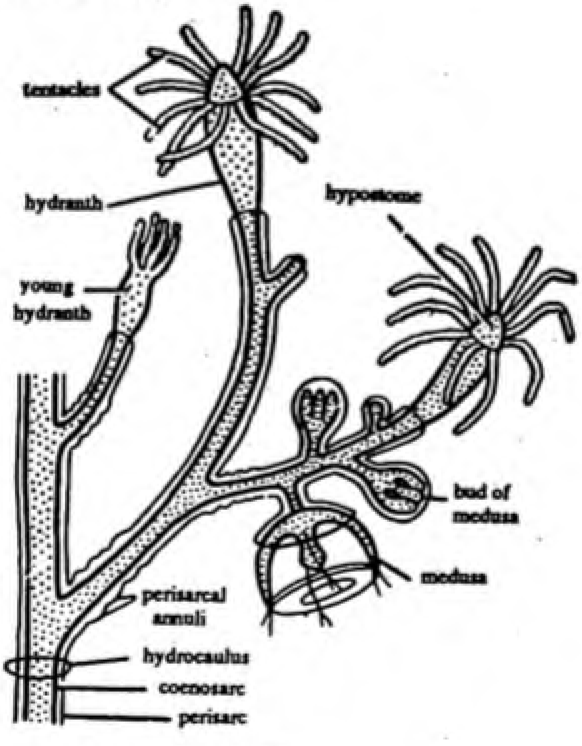


Fig. 23.6 *Bougainvillia*

1. It is a plant-like hydroid colony inhabiting in sea waters.
2. Two types of zooids are present the *polyp* or hydranth and *medusa.*

3. Polyps are vegetative responsible for nutrition and food catching, while medusa is reproductive in function.
4. Hydrotheca and gonotheca coverings are absent on polyps and medusae respectively.
5. Polyp is beset with a single circlet of filiform tentacles which surrounds the hypostome.
6. Medusa bears four radial canals and a wide velum.
7. On the manubrium of medusa develops the gonads.

Fig. 23.7 *Millepora*

MILLEPORA

Phylum	-	Coelenerata
Class	-	Hydrozoa
Order	-	Hydrocorallina
Suborder	-	Milliporina
Genus	-	*Millepora*

1. Marine colonial form found in tropical seas and associated with other corals.
2. Ectoderm secretes a calcareous yellowish or white skeleton of perisarc.
3. The dried coloney is perforated by numerous pores. These are of two different sizes; large *gastropores* and small *dactylopores* which surround the gastropores.
4. In living specimens two types of zooids - *gastrozoods* and *dactylozoids* which protude out of these pores.
5. Gastrozooids are feeding zooids, having 4-5 short knobbed tentacles. The dactylozooids are protective zooids with capitate tentacles having nematocysts.
6. Pores lead into canals which forms network in coenosarc.
7. Medusae with 4 or 5 rudimentary tentacles. These are free, simple and originate from coenosarc.

STYLASTER

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Hydrocorallina
Suborder	-	Stylasterina
Genus	-	*Stylaster*

1. It is highly branched, tree-like, deep pink coloney found in tropical and subtropical seas.
2. Numerous upright branches of calcium carbonate.
3. On the branches are cup-shaped projections formed of several zooids.
4. Gastrozooids situated in the centre, while *dactylozooids* are in the periphery.
5. *Gonophores* or reproductive zooids are lodged in a special chamber or *ampulla* of the coral.
6. From the horizontal partition, at the bottom of each cup, projects a calcareous projection called *style*, hence the generic name *Stylaster* is given.

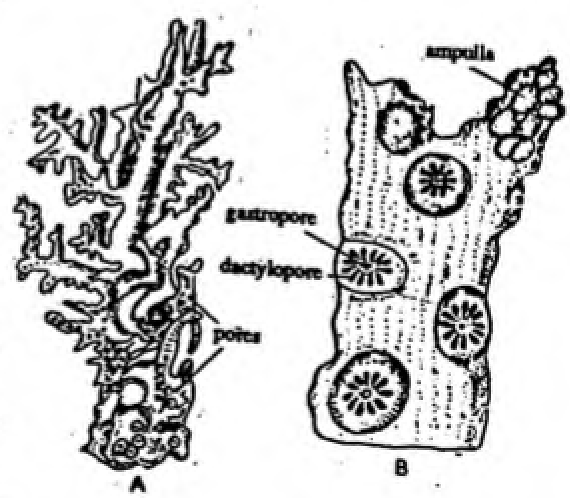


Fig. 23.8 *Stylaster*

7. The young sets free in the planula stage which later on metamorphoses into a new colony.

GONEONEMUS

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Trachylina
Genus	-	*Goneonemus*

1. It is a medusa found in bottom of sea water. It is cosmopolitan in distribution.
2. It is like the medusa of *Obelia* and generally bell-like or saucer-shaped.
3. The convex outer surface of the bell is known as exumbrella while the concave inner surface is subumbrella.

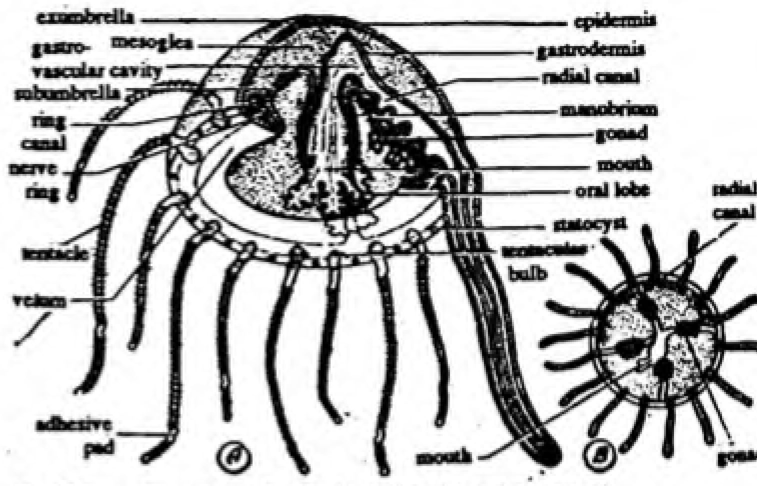


Fig. 23.9 *Goneonemus* A—Section to show internal structure, B—Sub-umbrellar side

4. From the centre of the concave or subumbrella surface hangs down a short, hollow and quardrangular process known as the manubrium bearing four brief frilled oral lobes surrounding the mouth.
5. The rim of the margin of the medusa bears numerous 16 to 18 highly contractile tentacles provided with belts of nematocysts and adhesive pads.
6. The adhesive pads are generally situated at the bending on each tentacle and helps in anchoring to marine plant at rest.
7. The gonads are situated on four radial canals and medusae are unisexual.
8. Planula develops into small polyp which has mouth, tentacles and is known as *haleremite*.
9. The haleremite reproduces asexually and gives rise to planula-like buds which are nonciliated and are called *frustules*.
10. The frustules develop into new polyps which from external side bud off gonophores. These naked gonophores give rise to medusae.

HALISTEMMA

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Siphonophora
Suborder	-	Physophorida
Genus	-	*Halistemma*

1. It is a polymorphic colony found floating on the surface of sea in Mediterranean.
2. Uppermost end of the stem possesses an ovoid bubble-like body, containing air, known as *float* or *pneumatophore*.
3. Below the pneumatophore, there is a series of unsymmetrical medusae, called *nectocalyces* each having a deep bell-like body with a velum and without manubrium.

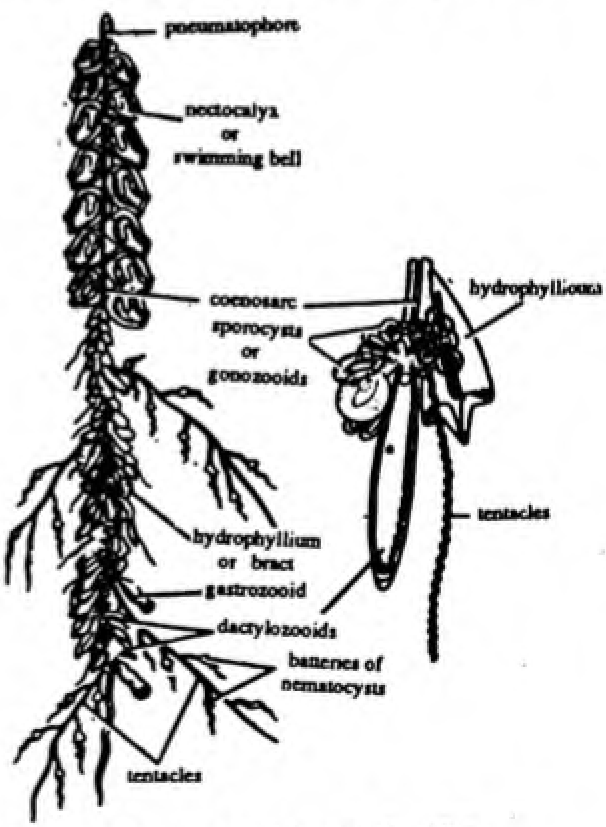


Fig. 23.10 *Halistemma* A—Colony, B—Cormidium

4. *Swimming bells* or *nectocalyces* contract, drawing water into their cavities and pumping it out to propel the whole organism through water.
5. Stem underneath divides into nodes and internodes.
6. Below certain nodes arise *polyps* with a long, branched tentacle and bearing batteries of "stinging capsule".
7. In the remaining nodes, *dactylozooides* or *feelers* take the place of polyps.
8. Below these dactylozooids are *sporosacs*, some are males and other females.
9. Delicate leaf-like, transparent bodies, the bracts or *hydrophylia*, spring from internodes.

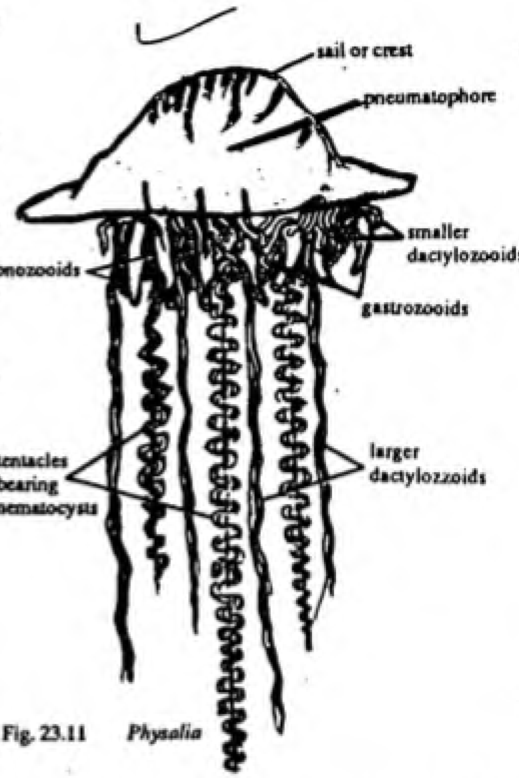


Fig. 23.11 *Physalia*

PHYSALIA

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Siphonophora
Suborder	-	Physophorida
Genus	-	*Physalia*

1. It is a marine, pelagic, polymorplic hydroid.
2. It is found in the gulf stream from Florida to Vineyard Sound and occassionally to the Bay of Fundy.
3. It is commonly called 'Portuguese man of war', because it has a large, brilliant colour pneumatophore or float which is like the cap of Great Napolean.
4. The dorsal side of float is called crest or sail.
5. The float is filled with a gas. The composition of the gas is 85 - 91% nitrogen, 1.5% argon and 7.5 - 13.5% oxygen.
6. The float or pneumetophore has a pore called pneumatopore.
7. The swimming belts or nectocalyces are absent.
8. Hanging from the underside of pneumatophore are three types of zooids:
   (i) *Gastrozooids* are nutritive zooids without tentacles.
   (ii) *Blastostyles* are reproductive zooids containing serveral medusae.
   (iii) *Dactylozooids* are the protective zooids with tentacles and nematocysts.
9. The female gonophores are medusoid and swim free, while male ones are small and remain attached.
10. The sting of *Physalia* is very poisonous and the nematocysts are so highly poisonous as to cause danger to man.

Fig. 23.12 *Porpita*

PORPITA

The classification is the same as that of *Physalia*.

1. *Porpita* is a marine coelenterate found usually on South Atlantic Coast and

occassionally near U.K. Coast.

2. The float is very large, circular and disc like (like the float of *Physalia*).
3. The colony consists of disc-like body enclosing a chambered chitinoid shell.
4. It exhibits the remarkable phenomenon of *polymorphism*.
5. Long dactylozooids or tentacles are present around the disc.
6. The under-surface is beset with gonozooids or blastostyles provided with mouth bearing the medusae.
7. The single gastrozooid is present in the centre of disc on ventral side as *Velella*.
8. Crest is wanting.

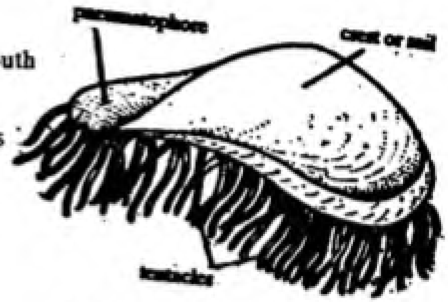


Fig. 23.13 *Valella*

VELELLA

The classification is the same as that of *Physalia*.

1. It is a beautifully coloured pelagic form found in warm water. It is common is Pacific coast, South Atlantic Coast.
2. Body rhomboidal with a medusa - like appearence.
3. Pneumatophore dorsal, in the form of a chambered chitinous disc and bears a vertical crest like ridges.
4. Hanging from the centre of the under surface is a single large gastrozooid which is surrounded by numerous gonozooids which give off medusa - buds.
5. The gonozooids are devoid of tentacles.
6. Dactylozooids hang down from the rim of the disc forming a circular fringe.
7. It is incapable of sinking down by altering the gas contents of the float.

LUCERNARIA

Phylum	-	Coelenterata
Ciass	-	Scyphozoa
Order	-	Lucermnarida
Genus	-	*Lucernaria*

1. It is a seentary, sessile animal found on British Coast.
2. Body is trumpet-shaped or conial differentiated into aboral exumbrella and oral subumbrella surface.
3. Exumbrella surface drawn out into a short, cylindrical stalk used for attachment to sea-weeds.
4. Margin of umbrella drawn into 8 short and hollow adhesive lobes or adradial arms.
5. Each arm bears a cluster of knobbed adhesive tentacles.
6. Mouth is cruciform (four cornered) with small oral lobes and a short manubrium.
7. Gastrovascular system consists of central stomach and four perradial pouches divided by four interradial septa.
8. Gastric filaments numerous.

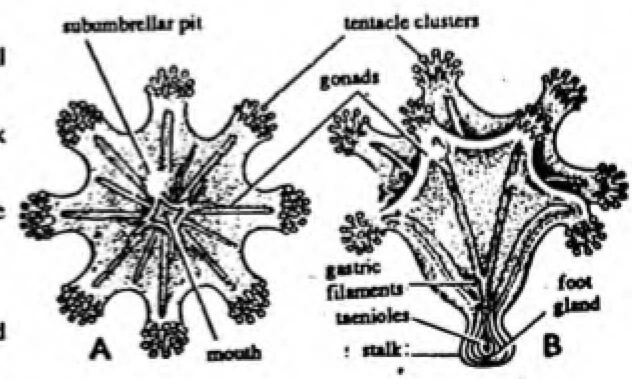


Fig. 23.14 *Lucernaria* A—oral view, B—side view

9. Gonads are band-like borne on septa.
10. Marginal adhesive gastric pits and velum are absent.

CHARYBDAEA

Phylum	-	Coelenterata
Class	-	Scyphozoa
Order	-	Cubomedusae
Genus	-	*Charybdaea*

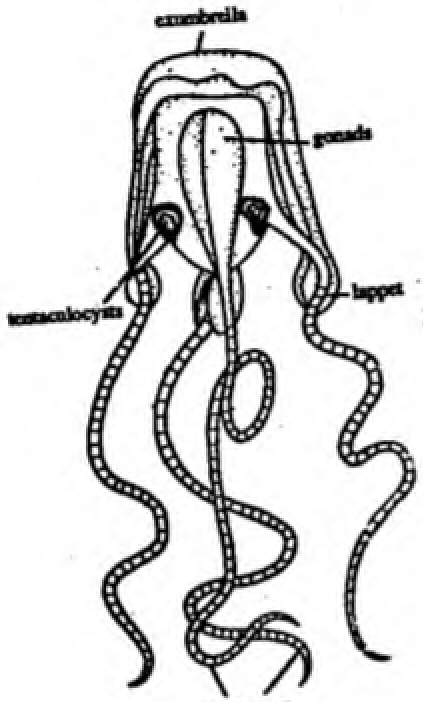


Fig. 23.15 *Charybdea.*

1. It is a marine animal. It is commonly found in the warm shallow waters of tropical and subtropical region.
2. It is an active swimmer and swim through the water appearing beautiful.
3. These resemble a deep bell with somewhat flattened top and square in transverse section.
4. The margin of the umbrella bears 4 tentacles and 4 tentaculocysts.
5. The tentacles are interradial and tentaculocysts are perradial.
6. The tentaculocysts are set in deep marginal notches and the tentacles arise from gelatinous lobes.
7. The tentaculocysts are very complex, each bearing a lithocyst and several eye-spots.
8. The margin of the umbrella is produced into a false velum like the velarium of *Aurelia.*
9. The nervous system is present in the form of nerve ring round the margin of bell.

PERICOLPA

Phylum	Coelenterata

Class	-	Scyphozoa
Order	-	Coronatae
Genus	-	*Pericolpa*

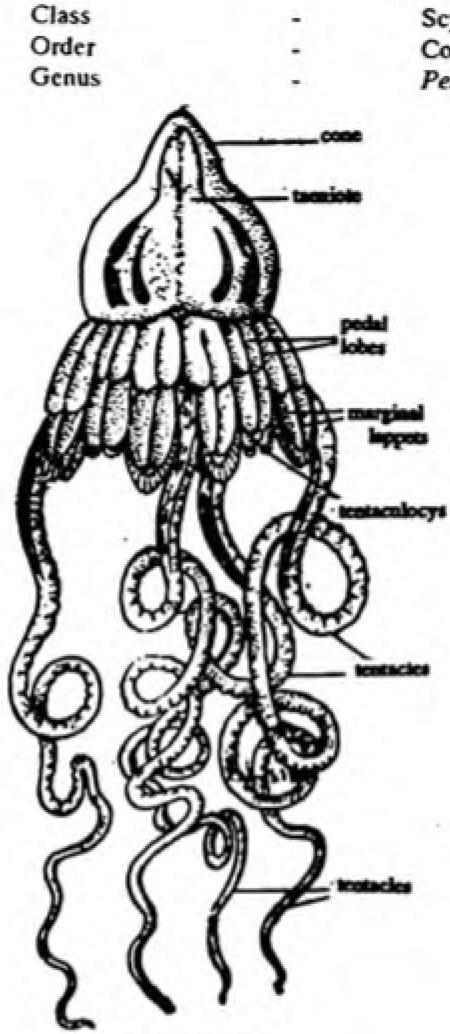


Fig. 23.16 *Paricolpa.*

1. It is a beautiful marine solitary medusoid animal.
2. It is cosmopolitan is distribution, but abundent found in Greenland.
3. Umbrella is divided into apical cone and marginal crown by a furrow.
4. Marginal crown is divided into a series of pedal lobes and series of marginal lappets by a second horizontal furrow.
5. Marginal lappets and pedal lobes are present in same radii.
6. Tentaculocysts are present on four interradial pedal lobes.
7. Large mouth opens into the stomach by manubrium.

CYANEA

Phylum	-	Coelenterata
Class	-	Scyphozoa
Order	-	Semaeostomeae
Genus	-	*Cyanea.*

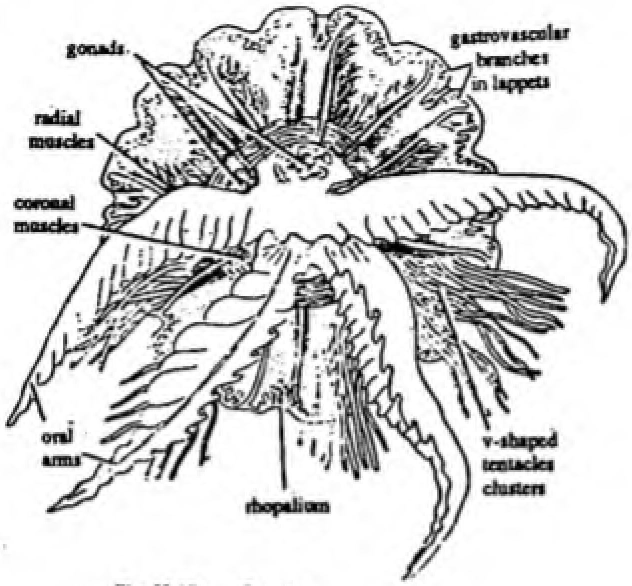


Fig. 23.17 *Cyanea*.

1. It is the largest, solitary, bioluminescent and marine medusa.
2. It is found in the costal waters of America, Pacific coast and polar regions.
3. It is commonly called as 'sun-jelly' or 'sea - blubber'.
4. Umbrella dome - shaped or saucer - shaped with margin scalloped into eight lappets having eight rhopalia.
5. Subumbrella carries four long oral arms and eight V-shaped bundles of tentacles, the marginal tentacles.
6. Four gondas, placed between oral arms and tentacles.
7. Circular canal absent. Radial canals branch profusely and extend into rhopalia and tentacles.
8. It produces burning sensation.

RHIZOSTOMA

Phylum	-	Coelenterata
Class	-	Scyphozoa
Order	-	Rhizostomae
Genus	-	*Rhizostoma*

1. It is inhabitant of shallow water in tropical and subtropical zones, sometimes, in temperate zones. These are also found in Indo-Pacific region and North Carolina.
2. The colour varies. The colour of umbrella is pale green with a deep reddish margin, arms bright blue.
3. The marginal tentacles are absent.
4. The original four arms become divided longitudinally into eight.
5. The mouth is one in young but it is replaced by numerous small "sucking mouths" in adult which lie along the lips.
6. Lips act as organs for external digestion.

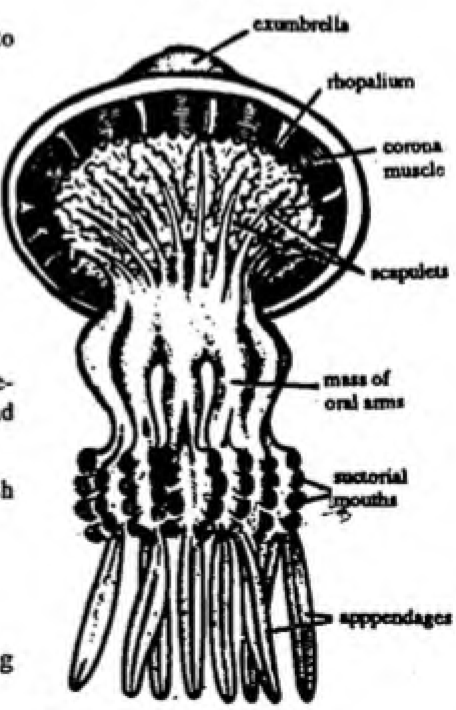


Fig. 23.18 *Rhizostoma*.

7. It feeds upon small animals like fishes etc.
8. The mesogloea of the medusae of *Rhizostoma* is neither gelatinous nor mucilaginous. The entire medusa contains 91 to 96% water content.
9. The umbrella is about 2' in length and specimen is about 4'.

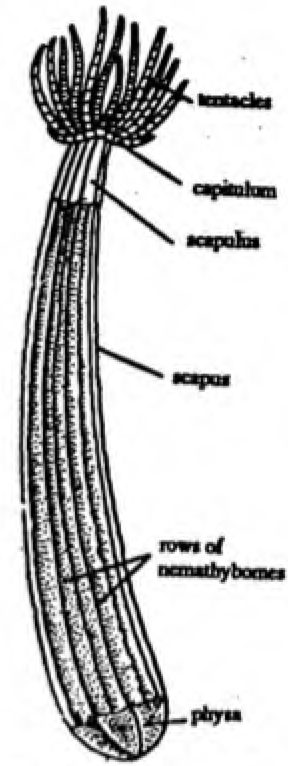


Fig. 23.19 *Edwarsia.*

EDWARDSIA

Phylum	-	Coelenterata
Class	-	Anthozoa
Subclass	-	Hexacorallia
Order	-	Actinaria
Genus	-	*Edwardsia*

1. It is a small, solitary, marine animal, buries in sand. It is found in U.S.A., Southern California and North of Cape Cod.
2. Body is elongated and is differentiated into oral disc and column.
3. Oral disc is short and carries centrally placed mouth and a circlet of 16 tentacles arranged in two rows.
4. The cylindrical column has three parts, the capitulum, scapulus and scapus.
5. The body surface has 8 longitudinal ridges and the posterior half of the scapus contains rows of nematocysts called as *nemathybomes.*
6. The basal part or *physa* is demarcated by limbus from scapus.
7. Siphonoglyphs and mesenteries are 8 in number are present.
8. Septa are in primitive condition consisting of 8 macrosepta and more than 4 microsepta.
9. The young of *Edwardsia* is parasitic in Ctenophore.

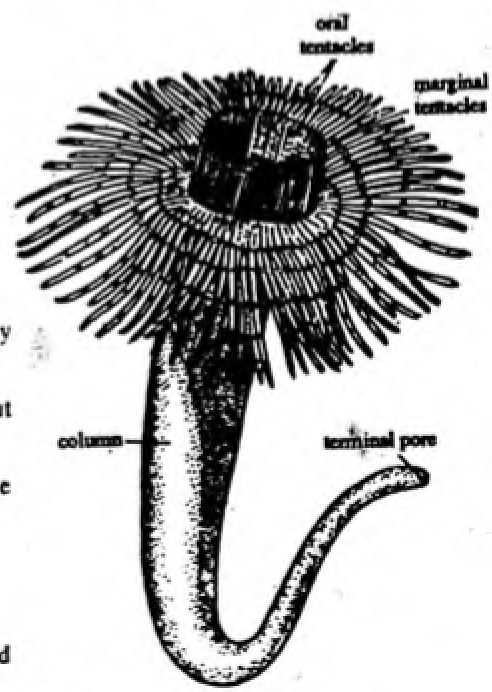


Fig. 23.20 *Cerianthus.*

CERIANTHUS

Phylum	-	Coelenterata
Class	-	Anthozoa
Subclass	-	Hexacorallia
Order	-	Ceriantharia
Genus	-	*Cerianthus*

1. It is found along the Pacific and Atlantic Coast, Cape Cod to Florida, Bay of Fundy and Mediterranean.
2. The form resembles a sea anemone and has cylindrical elongated body but without pedal disc.
3. The oral region has numerous tentacles about 130 arranged in 2 rows, the marginal whorl of tentacles and inner circlet of tentacles.
4. The lower end is round and has terminal pore.
5. Pharynx has only one siphonoglyph.
6. The ectoderm secretes long tube of mucus in which the animal lives and the tube is fixed in soft, sandy or mud sea bottom.
7. On the tube sand particle are deposited so it becomes hard.

ZOANTHUS

Phylum	-	Coelenterata
Class	-	Anthozoa
Subclass	-	Hexacorallia
Order	-	Zoantheria
Genus	-	*Zoanthus*

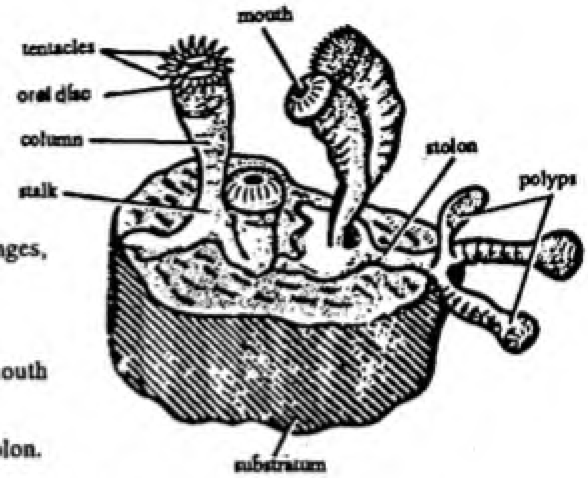


Fig. 23.21 *Zoanthus.*

1. It is a colonial form found attached to rocks or corals, sponges, shells etc.
2. It is found is West Indies.
3. Body is differentiated into column and oral disc having mouth and marginal tentacles.
4. Cylindrical, small polyps arise singly from a network of stolon.
5. Tentacles are numerous, 48-60 in number arranged in one or two rows.
6. Mesenteries paired consisting of both micro- and macro-mesenteries.
7. Single siphonoglyph present.
8. Sexes are separate and asexual reproduction by budding.

MADREPORA

Phbylum	-	Coelenterata
Class	-	Anthozoa
Sub class	-	Hexacorallia
Order	-	Madreporaria
Genus	-	*Madrepora*

Fig. 23.22 *Madrepora.*

1. It is a colonial, symbiotic and marine coral found in West Indies and Florida.
2. It is commonly called as 'horn coral' and plays an important role in coral-reef formation.
3. Coloney is branched with numerous, small crowded polyps in elevated cylindrical cups separated by coenosteum.
4. Terminal polyps contain 6 tentacles and lateral polyps with 12 tentacles.
5. Internally mesenteries are bilaterally arranged and coenosarc contain a network of canals.
6. Sometimes small crustaceans are found in association with horn corals.

MEANDRINA

The classification is the same as that of *Madrepora*.

1. Colonial form inhabiting the coastal waters of West India, Asia and America.
2. It is popularly known as 'brain-coral' since resembles the human brain due to the presence of long curved grooves and ridges.

Fig. 23.23 *Meandrina.*

3. The colony is large and is composed of lime stone secreted by ectoderm.
4. Polyps bear separate mouth, tentacular fringe, septa and mesenteries.
5. Polyps remain confluent in the living condition.

FAVIA

The classification is the same as that of *Madrepora.*

1. *Favia* is a massive stony red building coral.
2. It is commonly found in Florida and West Indies.
3. *Favia* has a compact and huge colony produced by buds.
4. The surface of the colony has closely placed polygonal cases or cups.
5. The cups are so near to each other as to have common boundries.
6. The skeleton which is very hard, is made up of calcium carbonate material and secreted by ectoderm for support of delicate tissue.
7. The polyp is like that of sea anemones which contract in cups and are without siphonoglyph.
8. Columella present.
9. The *Favia* is aporose corals as the various parts of coral and solid and stony.

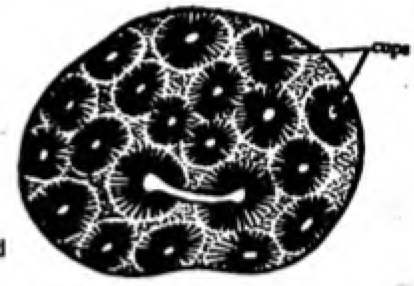


Fig. 23.24 *Favia.*

FUNGIA

The classification is the same as that of *Madrepora.*

1. It is a solitary and marine coral found in warm sea, generally in Gulf of California.
2. It is commonly called as 'mushroom coral'.
3. The coral is flat and discoidal, the theca is confined to the lower surface and small calcareous rods and synapticulae, which connect septa with one another.
4. Adult animal contains a single large polyp with numerous tentacles.
5. Siphonoglyphs are absent.
6. The life-history includes planula larva which metamorphoses into adult.
7. Reproduction by monodisc strobilation that is plate-like structures are separated off one by one from the top of corallite. The broken disc are called *anthocyanthus* and develop its adults. The remaining broken part is called *anthocaulus* which grows again into new disc and is set off.

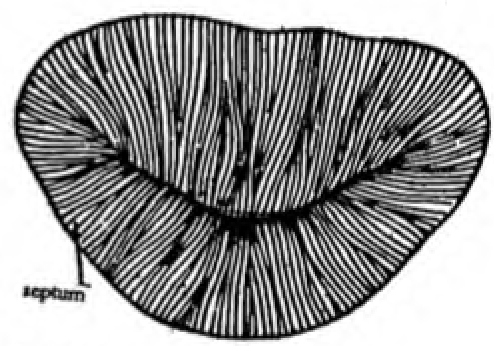


Fig. 23.25 *Fungia.*

ASTRANGIA

The classification is the same as that of *Madrepora.*

1. It forms small encrusting colonies and found on rocks and shells.

   - *Astrangia* is found along the coasts of Atlantic and America.

2. Colony consists of theca and polyps.

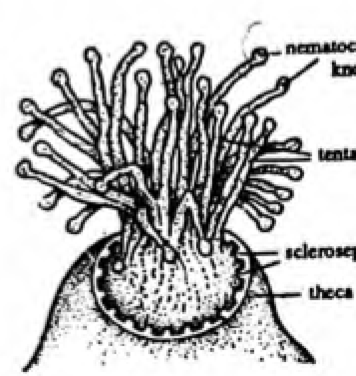


Fig. 23 › *Astrangia.*

3. Poly[illegible]s are white pinkish or greenish in colour.
4. Zoo[illegible]re more or less isolated with six sepata of the first cycle, six sma[illegible]s of the second and fourth cycles.
5. Mouth is present on the oral disc, which is surrounded by double rings of tentacles.
6. Bigger polyps have three cycles of tentacles mostly 12 larger tentacles alternating with 12 smaller tentacles.
7. It feeds on crustaceans and small fishes.

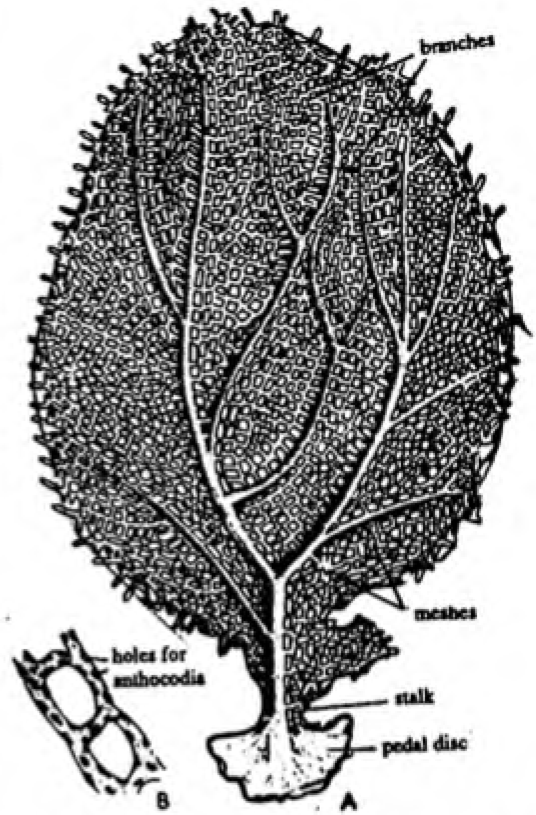


Fig. 23.27 *Gorgonia.* A—Coloney, B—A portion megnified.

GORGONIA

Phylum	-	Coelenterata
Class	-	Anthozoa
Subclass	-	Octocorallia
Order	-	Gorgonaria
Genus	-	*Gorgonia*

1. These are present in all the seas attached to rocks and stones in shallow waters.
2. It is commonly known as 'sea-fan'.
3. It is yellowish or brownish colony with upright branches consisting of an axial rod extending throughout the coloney along all the branches.
4. The skelton is made up of a flexible substance gorgonin and calcareous spicules embedded in mesogloea.
5. Polyps or *anthocodia* are retractile and present in rows on both the sides of the branches.
6. Sexes are separate.
7. The dried skeletons of the colony are used in decorative art.

TUBIPORA

Phylum	-	Coelenterata
Class	-	Anthozoa
Subclass	-	Octocorallia
Order	-	Alcyonaria
Genus	-	*Tubipora*

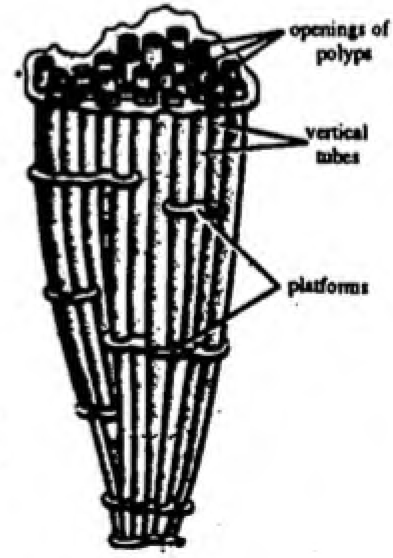


Fig. 23.28 *Tubibora.*

1. It is a marine, colonial animal found in shallow water of tropical and temperate regions.
2. It is found abundantly in shallow waters of Atlantic, Indian and Pacific oceans.
3. It is commonly called 'organ pipe coral'.
4. Coloney consists of long, parallel and upright tubes closely fitted, and joined together at definite interval by horizontal calcareous tubes.
5. The polyps are bright green and secrete these tubes.
6. The skeleton is internal and is covered by ectoderm in living condition.

7. The mesogloeal spicules become closely fitted together and form a continuous tube for each polyp.

8. Asexual reproduction by peculiar budding. The base of original polyp expands from which new polyps originate.

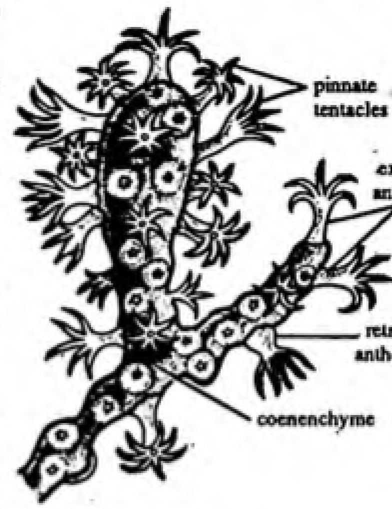


Fig. 23.29 *Corallium.*

CORALLIUM

The classification is the same as that of *Tubipora.*

1. It is a colonial marine animal commonly found in Mediterranean at a depth of 10-30 fathoms, Cape Verde Island, Japan, Italy etc.
2. It is commonly called 'red coral'.
3. The colony is upright and branched and is supported by calcareous axis of fused spicules.
4. The colony is dimorphic as there are two type of zooids (i) nutritive zooids, the *autozooids* and (ii) for circulation of water in the colony, the *siphonozooids.*
5. The zooids are white in colour and the colony is dark red due to the presence of red calcareous spicules.
6. Gonads are borne by siphonozooids.
7. Planula develops inside the zooids and so that vivipary is found in *Corallium.*
8. The *Corallium* is of great economic importance as the precious red coral of commerce known as red moonga in N. India which is obtained from this animal.

Fig. 23.30 *Alcyonium.*

ALCYONIUM

The classification is the same as that of *Tubipora.*

1. *Alcyonium* or Dead man's finger is found attached to stones or rocks in sea water.
2. Cosmopolitan is distribution, but mostly found in temperate and cold water of sea. Commonly found in long Island and St. Lawrence.
3. Colony of short and thick leathery lobes attached to stones.
4. Long polyps with tentacles except those of the outer end, polyps with tentacles can be contracted and everted.
5. *Coenenchyme* (mesogloea or soft parts of an alcyonarian colony), flesh and spicules present.
6. Colour of the colony is redish or yellowish; length is 4 to 10 cm.
7. The skeleton consists of calcareous spicules.
8. The food (In *A. digitatum*) consists of various fine fragments of muscles of fish but they may reject many kinds of fish ova (according to *Pratt*).
9. Gland cells occur in stomodaeum and it is probable thet they secrete a fluid for digestion.
10. The polyps are arranged on the upper part of the colony, and the lower part is sterile.

HELIOPORA

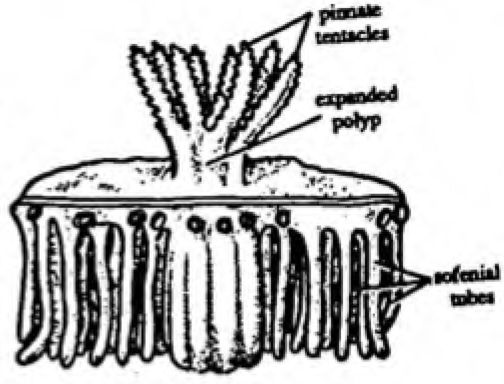


Fig. 23.31 *Heliopora.*

The classification is the same as that of *Tubipora.*

1. It is a marine, sedentary coral found on coral reefs in the Indo-Pacific ocean.
2. It is commonly called as 'blue coral' because of the bright blue skeleton. The blue colour is due to iron salts.
3. Its massive skeleton, composed not of spicules but of crystalline fibres of arragonite fused into lamellae.
4. Skeleton is perforated by large pores through which ordinary polyps project out, and smaller pores through which siphonozooids project out.
5. It is traversed by tubular cavities of two sizes, larger cavities - few in number open out through large pores. Smaller cavities open out through small pores.
6. Surface contains flat coenenchyme, which contains solenial network connected to middle region of the polyp and also with erect solenial tubes.
7. Polyps dimorphic, large ordinary zooids and small siphonozooids.

PENNATULA

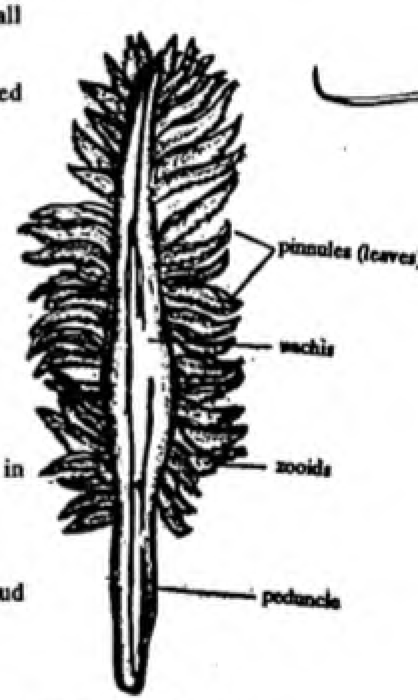


Fig. 23.32 *Pennatula.*

Phylum	-	Coelenterata
Class	-	Anthozoa
Subclass	-	Octocorallina
Order	-	Pennatularia
Genus	-	*Pennatula*

1. It is found fixed deep is muddy bottom of the sea. It is commonly found in Europe, South California northward, Gulf of St. Lawrence to Carolina.
2. It is commonly called 'sea pen'.
3. Colony is divided into two parts: (a) stalk, which is embedded in sand or mud and (b) an upper part, called the *rachis* or *horny axis.*
4. *Rachis* is elongated with paired lateral leaves or *pinnulae.*
5. Lateral leaves or pinnulae long, from 20 to 25 in number on each side.
6. Polyps, arranged on horny axis, are of two types:-
   (a) *Autozooids,* whose function is nutritive, are situated side-by-side as regular lateral branches giving an appearance of a feather.
   (b) *Siphonozooids,* which maintain circulation of water in the colony, are situated on the back of the axis.

RENILLA

The classification is the same as that of *Pennatula.*

1. It is a marine, colonial form found in shallow waters of the Carolina Coast, California Coast and West Indies.
2. Colony composed of a small *peduncle* which lie embedded in the mud and a kidney-shaped *rachis.*
3. Rachis has a broad ventral surface devoid of polyps and a dorsal surface covered with autozooids and siphonozooids.

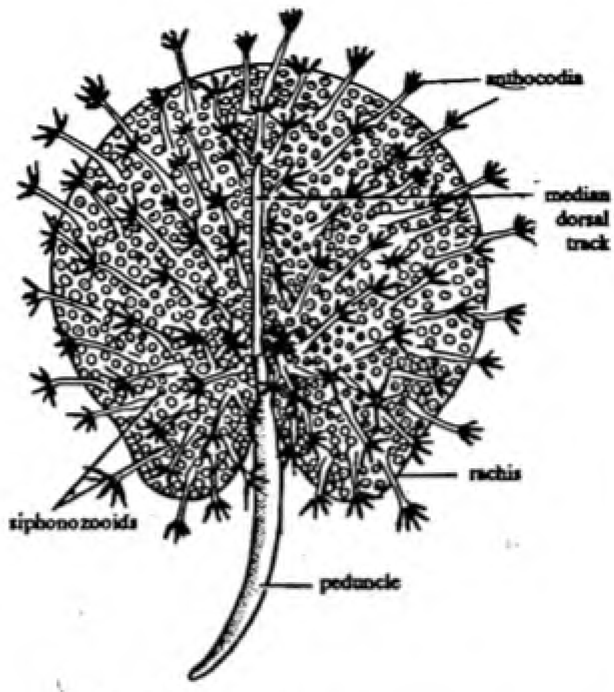


Fig. 23.33 *Renilla.*

4. *Autozooids* or *anthocodia* lie scattered on the dorsal surface and are nutritive in function.
5. *Siphonozooids* are arranged in groups and maintain the circulation of water within the colony.
6. A median bare 'track' devoid of polyps extends from the peduncle to about the middle of rachis, where it terminates at a special exhalent siphonozooid.
7. Axial skeleton absent.

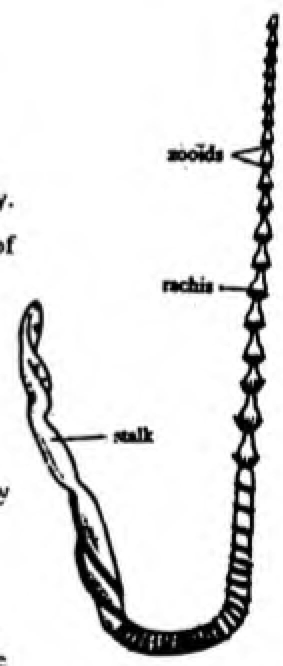


Fig. 23.34 *Virgularia.*

VIRGULARIA

The classification is the same as that of *Pennatula.*

1. *Virgularia* or "walking stick" is found partly embedded in warmer water having a muddy and soft bottom. It is found along Pacific Coast.
2. The rachis is long and elongated like a walking stick.
3. The elongated body is divisible into two parts, *a stalk* and the *rachis.*
4. The polyps arranged in transverse rows at regular intervals and are slightly fused and arise from the *rachis.*
5. The stalk is without polyps.
6. The stalk is thrust into the muddy bottom.
7. The distal rachis stand straight outside water.

CAVERNULARIA

The classification is the same as that of *Pennatula.*

1. It is a colonial, marine animal found along the Atlantic Coast.

2. Body is divisible into a proximal stalk or stem which is devoid of anthocodia and a distal rachis having secondary polyps.
3. The colour is blue or violet, may be yellowish or greenish.
4. Anthozooids and siphonozooids are irregularly distributed all over the rachis.
5. Anthozooids having tentacles and gonads.
6. Coenosarc is fleshy and traversed by coenosarcal canals and contains long spicules.
7. It is a bioluminescent, emits light.

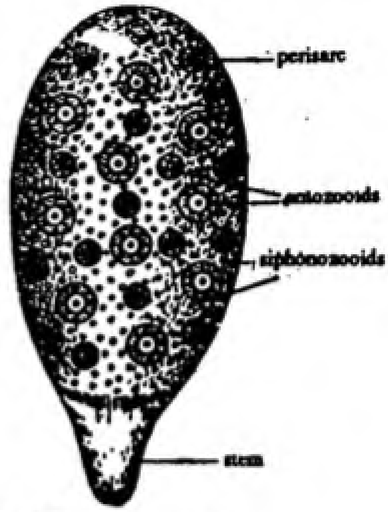


Fig. 23.35 *Cavernularia.*

24

HYDRA

Hydra belongs to the family Hydroidae and is characterized by the complete absence of perisarc and the presence of hollow tentacles. Some of the important species of *Hydra* comprise:

(i)*H. vulgaris*. Nearly colourless and common all over India. Tentacles are slender and not longer than the body.

(ii)*H. virids* (*Chlorohydra virisdissima*). It is the common green hydra because of the presence of symbiotic algal organism, *chlorella vulgaris* in the cells of the gastral epithelium. It has not yet reported from India.

(iii)*H. fusca*. It is a pinkish yellow or brown in colour and occurs in few parts of India.

(iv)*H. gangetica*. It is commonly found in ponds along the river Ganga in India.

Hydra americana has shorter tentacles than the column *H. pseudoligactis* has distinct stalk at the basal end. *H. oligactis* lacks nipples on the testes.

The name *Hydra* was given after a mythological nine headed scaly, winged armoured fire breathing monster slain by *Hercules.*

SYSTEMATIC POSITION

Phylum	-	Coelenterata
Class	-	Hydrozoa
Order	-	Hydroida
Suborder	-	Anthomedusae
Genus	-	*Hydra*

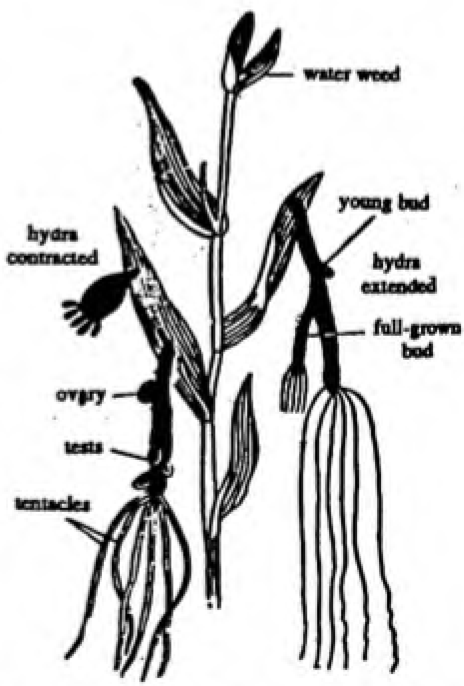


Fig. 24.1 *Hydra*. Contracted and extended

Habits and Habitat

Hydra lives in fresh-water ponds, lakes and streams attached to submerged water plants, rocks or other objects through its adhesive basal disc. It is cosmopolitan in distribution and prefers cool, clear, permanent and stagnant water. While feeding, the body and tentacles stretch in search of food. When disturbed, the body gets contracted into a circular knob-like structure. If the animal is taken out of water, it collapses into a soft shapeless mass. It is not found in places where water is foul and the temperature is high. It is a solitary creature, though at times it may form a temporary colony by repeated budding. It is carnivorous in diet, feeding on small crustaceans, worms and insect larvae. It is itself fed by some worms and molluscs. It multiplies sexually as well as asexually.

Collection

For collection of *Hydra*, they can be found in shallow water of ponds, lakes and streams and can be easily collected in early winter months. The acquatic vegetation containing these animals may be put in a jar full of pond water. To

separate them from the twig, a jet of water from pipette will separate them. When they are extended, they may be fixed in Bouin's fluid and stored in 70% alcohol.

Morp' logy

S' e. *Hydra* is easily visible to the naked eye. Its siz ranges from 2 to 20mm. in length. The great variation in length is due to the remarkable power of contraction and expansion possessed by it.

Colour. Colour varies from species to species. *Hydra vulgaris* is almost colourless, *Hydra oligactis* is brown, while *Chlorohydra viridissima* is green. The green colour of the last named species is due to the presence of a unicellular green alga (*Chlorella vulgaris*) in the cells lining the digestive cavity. Colour of *Hydra* often depends on the nature of food and hence cannot be used in identification of species with certainty.

Form. The body of *Hydra* has the form of a tube. Its proximal end is closed by flat disc termed the *basal disc* or *foot*. The latter fixes the body to the substratum by a sticky secretion and also helps in locomotion. It has in some species a pore which remains closed during attachment. The distal free end of the body has a small conical projection, the *hypostome* or *oral cone*, perforated at the apex by a circular aperture, the *mouth*. A ring of 4-12 fine hollow processes, the *tentacles*, surrounds the base of the hypostome. The number of tentacles differs between species and increases with the age of the animal. The size of the tentacles also varies with the species. They are shorter than the body in *Chlorohydra viridissima*, slightly longer than the body in *Hydra vulgaris* and much longer than the body in *Hydra oligactis*. The tentacles are highly extensible and may stretch out from short blunt projections to extremely thin threads 7 cm. or more long and hardly visible even with a lens. They are primarily meant for catching food, but are also used for locomotion. They are between the basal disc and the hypostome in the body proper or column.

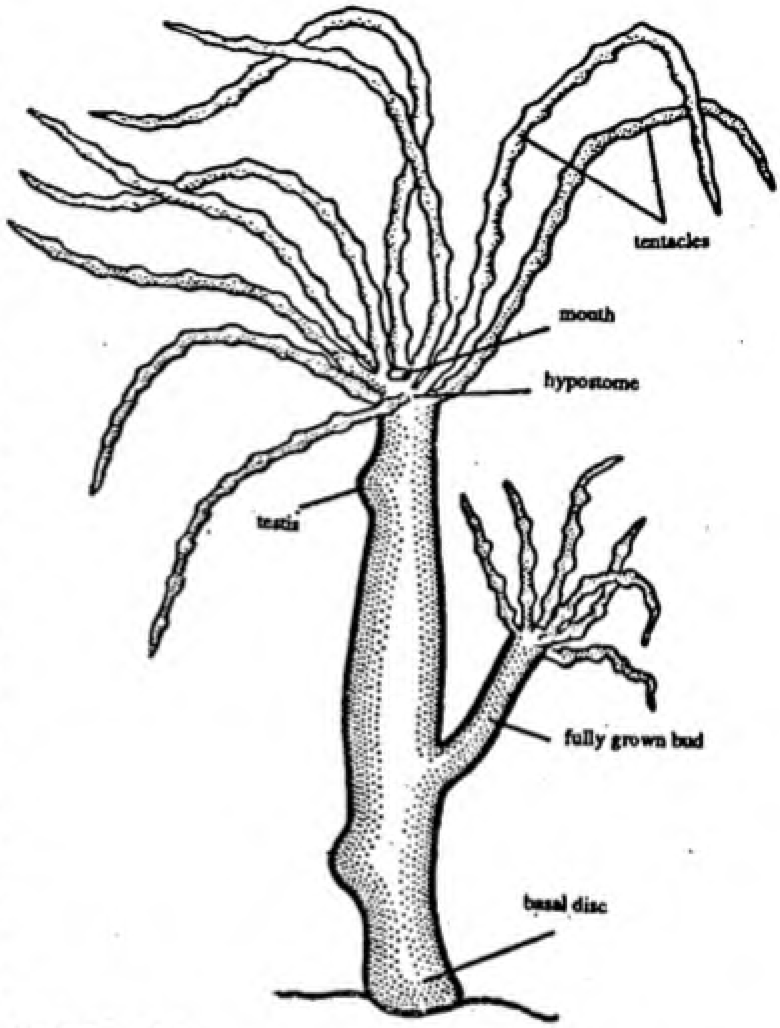


Fig. 24.2 *Hydra*

Often one to several buds are found in the column region, and these in turn may bear buds before detachment from the parent. In this way a sort of primitive *Hydra* colony is formed. In *H. oligactis*, there is a definite *budding zone*. Others less conspicuous structures that may be occassionally seen on the external surface of the column includes reproductive organs i.e. testes and ovaries. *Testes* are papillated conical elevations, situated near the hypostome while the *ovaries* are knob-like, usually located near the basal end. Reproductive organs are particularly prominent in the autumn and winter.

Histology

A longitudinal section of hydra shows a central cavity-the *gastrovascular cavity* or *coelenteron*, surrounded by a wall formed of two cellular layers, the *ectoderm* and *endoderm*. As these two terms are generally limited to embryological stages, as such in coelenterates, the two epithelia are now preferred to be called as *epidermis* and *gastrodermis* (*Hyman*, 1940). The epidermis and gastrodermis are joined together by a non-cellular gelatinous layer, called the *mesogloea*. Thus *Hydra* is *diploblastic* animal in contrast to higher animals which are triploblastic. Tentacles also posses these body layers. Both body and tentacles are hollow;

at the base of tentacles are present sphincters that are capable of shutting off the connection between the body cavity and the tentacular cavity. This arrangement prevents the entry of injurious material into the tentacular cavity from within the gastrovascular cavity.

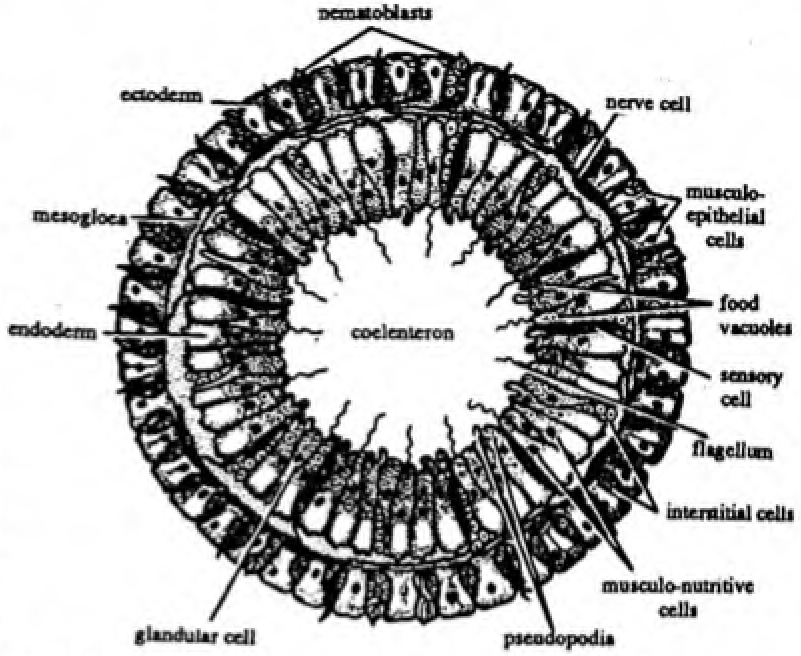


Fig. 24.3 T.S. of *Hydra*

Ectoderm: As stated already that *Hydra* is diploblastic i.e. made up of two layers: the *ectoderm* and, the *gasterderm*. Ectoderm is further composed of various cells given under the following sub heads:

(i) ***Epitheliomuscular cells.*** Epidermis is largely composed of cells of this type. They are cone-shaped, large-sized, having their broader part outside and inner part drawn out into contractible processes called *muscle tails*, these lie just outside the mesogloea and resting over it. The broader part of a cell press against those of neighbouring cells, thus epidermal cells form a continuous layer over the body surface, while the narrow inner parts leave narrow spaces between them. The outer border bears fine membrane-bound mucous granules that secrete a thick filamentous protective material outside. The cytoplasm of the cell has smooth and rough endoplasmic reticulum, free ribosomes, Golgi complex, number of mitochondria and quite a few intracellular space, and vacuoles. The adjacent cells are connected by septate desmosomes. Muscle-tails have longitudinally running contractile fibres, the *myofilaments*, that branch and anastomose, and one or more non-contractible supporting fibrils called *tonofibrils*. Longitudinal arrangement of muscle-tails allows contraction of the body along the long axis. Fine microtubules run parallel to myofilaments. They are believed to carry ions or water during contraction.

These epitheliomuscular cells show variation in different regions. In tentacles, the cells are large and have numerous cnidoblasts and more apical mucous glands with more elaborate endoplasmic reticulum. In the peduncle region, the cells are small and cuboidal and contain few intracellular spaces having mucous granules and irregular masses.

(ii) ***Glandulomuscular cells.*** The epitheliomuscular cells of the pedal disc are specialised to secret adhesive material to provide attachment to the substratum. The interior of these cells is filled with mucous granules which are elaborated by Golgi complex. The endoplasmic reticulum is well developed. The basal region of the cells have smaller mucous granules while the apex has larger ones.

(iii) ***Interstitial cells.*** In between the narrow ends of

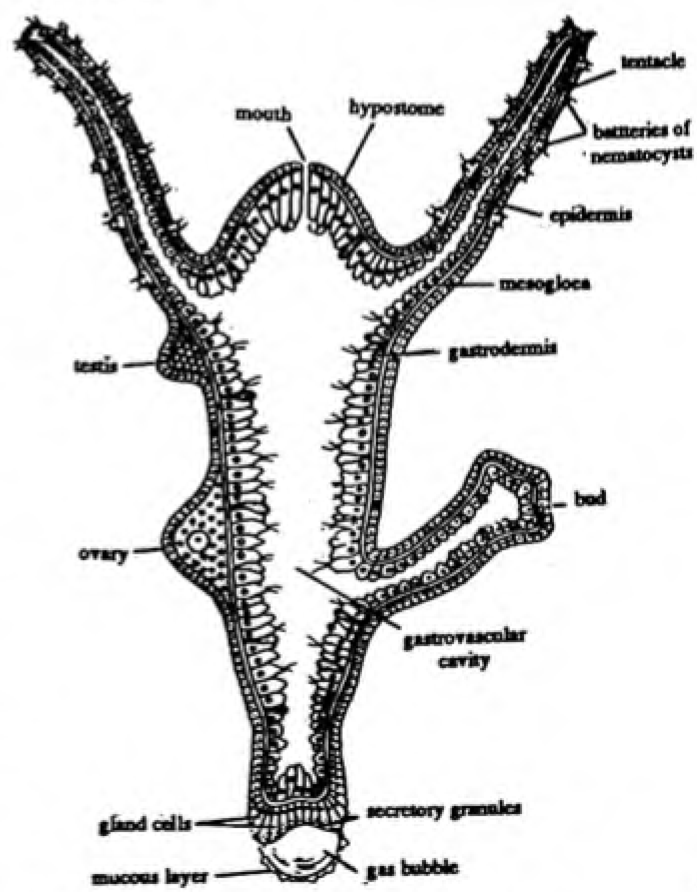


Fig. 24.4 *Hydra*. Longitudinal section of the body and tentacles.

epitheliomuscular cells, there are empty spaces (interstice) which are filled with small cells called interstitial or *formative* or packing cells. They are looked upon as embryonic cells, reminiscent of the archeocytes of Porifera, and are capable of giving rise to other cells of epidermis as well as forming nematocysts. At certain periods of the year some develop into reproductive cell. Thus interstitial cells play an important role in regeneration, growth, budding and sexual reproduction.

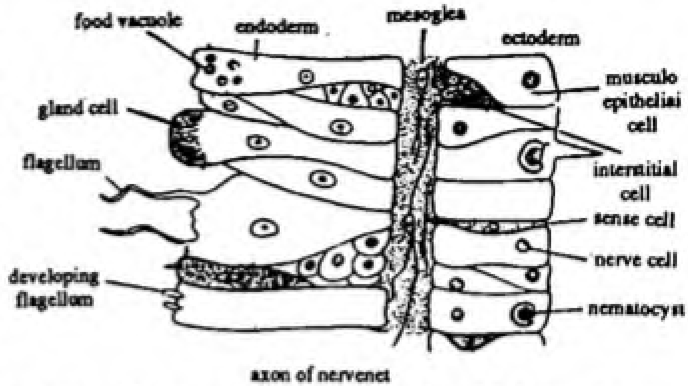


Fig. 24.5 Diagrammatic longitudinal section through the body-wall of *Hydra*.

(iv) ***Sensory cells.*** These are tall, narrow cells scattered amongst the epitheliomuscular cells and project over the surface by the single *sensory cilium* with rooting fibres lying in the cytoplasm. At the apical surface of the cell, which reaches the surface of the body, the plasma membrane is notched to form a collar for the cilium. The modified cilium consists of nine peripheral and more than two central fibrils. Their inner ends are drawn out not into muscle-tails but into thin *modulated fibres.* Small rooting fibres radiate out from the basal granule of the cilium. mitochondria, endoplasmic vesicles and microtubules are present.

The detailed study with the help of electron microscope shows that a single cilium-like process, the apical cilium, with 9+2 fibrillar pattern occurs in the apex of cell which is surrounded by a cell membrane. The basal end of the sensory cell either rests on the nerve cell or is connected to its process.

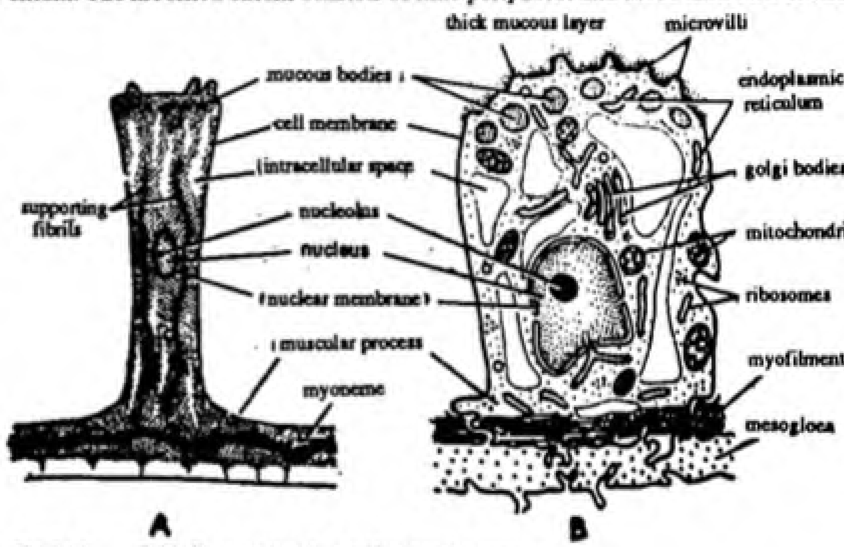


Fig. 24.6 *Epithelio* - muscle cell. A—Under light microscope. B—Under electron microscope.

(v) ***Nerve cells.*** The nerve cells or ganglion cells are small and elongated having one or more processes. They are situated at the base of the epitheliomuscular cells just above their muscular process. They are derived from the interstitial cells of epidermis. Each nerve cell consists of a small cell body with the nucleus and gives off two to several nerve processes or neuritis. The neuritis of adjacent nerve cells do not fuse but only touch each other. The nerve cells of the whole body are linked up by synoptic contacts to form a sort of nerve net. The nucleus, endoplasmic reticulum, scattered mitochondria, two or three groups of Golgi complex, many small and large fluid filled vesicles and microtubles which extend into nerve processes or neurities. The latter contain ribosomes, mitochondira, fluid-filled sacs and microtubules. The nerve cells of the basal part are devoid of microtubules.

(vi) ***Germ cells.*** During summer, the interstitial cells in certain restricted regions of the body repeatedly divide and proliferate reproductive cells forming gonads, which later differentiate into either *testes* or *ovaries.*

(vii) ***Cnidoblasts.*** Cnidoblasts or stinging cells are found scattered throughout the epidermis but are more abundant on the tentacles. These are developed by some of the interstitial cells which get specialised. When fully formed, they migrate towards the tentacles through the mesogloea by means of amoeboid movement. The cnidoblast cells are somewhat oval-shaped.

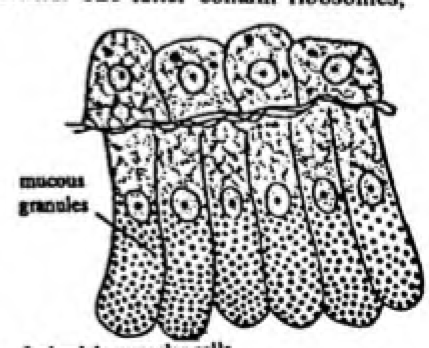


Fig. 24.7 Cell of *Hydra*

The cnidoblast possesses a thin cytoplasmic rim which surrounds the large centrally located nematocyst. The nucleus is situated between the nematocyst and plasma membrane and contains a small inconspicuous nucleolus. A few rough surfaced lamellae and isolated smooth surfaced vesicles of endoplasmic reticulum are present in the cytoplasm. Free ribosomes are also present. Small Golgi complex lies in the basal region. Mitochondira, lipid droplets and multivesicular bodies are located in the cytoplasm. Extending from the capsule of the nematocyst are a bundle of small myofilaments. A peculiar oval or pyriform sac or bladder filled with a poisonous fluid or *hypnotoxin*, which is a chemical mixture of proteins and phenols, is present. This is the stinging cell or *nematocyst*.

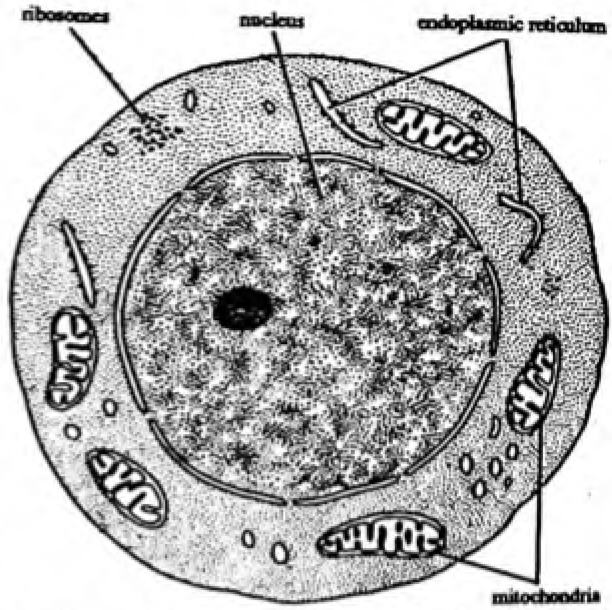


Fig. 24.8 Diagrammatic representation of an electron micrograph of an interstitial cell of *Hydra*

Nematocysts (Gr., *nema*, thread + *Kysics*, bladder) is a minute sac, 5 to 50 m in length. It is not a cell because it is chitinous and non-living. The outer end of nematocyst is invaginated into a long, hollow and tubular thread coiled like a wire-spring inside the sac. The tip of the thread tube is open and its base is swollen to form the shaft. The inturned thread is covered over at the base by an operculum. At the base of the thread tube are three large spine-like *barbs* or *stylets* which are directed inwards. There are three spiral rows of minute spines known as *barbules* or *spines*. A hair-like process, the *cnidocil* or trigger projects from the outer end of the cell and extends beyond the epidermal surface. A few supporting rods lie around the cnidocil. The cytoplasm of cnidoblast may have contractible muscle fibres. A restraining thread, the *lasso* is sometimes attached to the base of nematoblast which prevents the nematocyst from being thrown out of it.

The cnidocil is composed of a central core surrounded by large rods.

Origin and occurrence of nemotocyts. The nematocysts have their origin in the vacuoles of the interstitial cells. The cnidoblasts containing developing nematocysts migrate through the body wall into the etneron from where they are taken up by pseudopodia of endoderm cells and transferred to mesogloea through which they travel and migrate outwards through the body wall again and reach the final position complete the development. The cnidoblasts get fixed in the ectoderm with its base reaching the mesogloea while the cnidocil bores through the cutcile and projects outside. The nematocysts are scattered individually throughout the epidermis of the body except the basal disc where they are absent. They occur abundantly in the oral region and in the tentacles, as wart-like "nematycyst batteries", each battery consisting of one or two large central nematocysts surrounded by 10-12 smaller nematocysts. All of them are enclosed in a single larger epithelio-muscle cell. However, they are never formed in the tentacles but migrate from their place of origin in the epidermis of body.

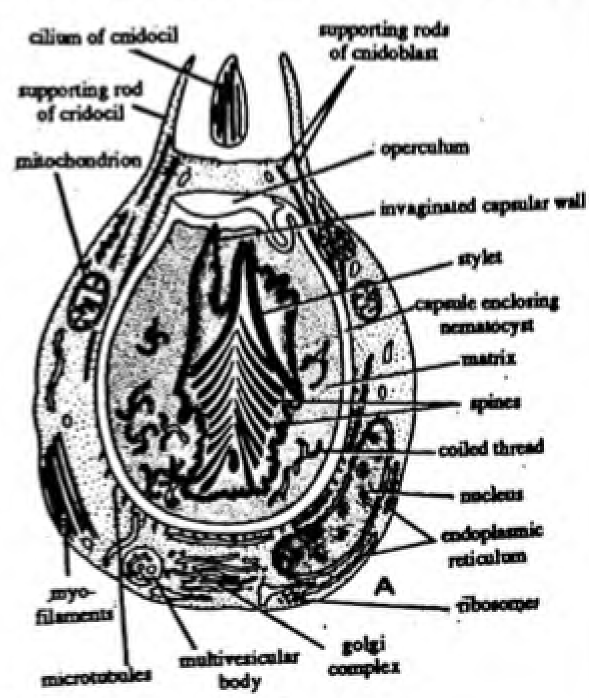


Fig. 24.9 Electron migrograph *Nimatoblast.*

The nematocysts are weapons of offense and defence of *Hydra*. They also serve in food capture, locomotion and anchorage.

Discharging of Nematocyst

The process of the discharge of nematocyst is quite peculiar. Whenever the cnidocil comes in contact with any object such

as protozoans, then a kind of stimuli passes through the cytoplasm of the nematoblast due to which the contractile fibrils surrounding the capsule contract. By the contraction of these fibrils pressure is exerted on the capsule due to which the operculum opens.

The pressure in the fluid of the capsule is increased so much that the whole funnel and the thread tube coiled around it immediately shoots out of the capsule. The thread of capsule penetrates the body of the animal. A poisonous substance comes out of the thread tube and enters the body of the animal, which becomes unconscious. Once discharged, the nematocyst becomes useless and drops off from the body of *Hydra*. A new nematoblast migrates to its place.

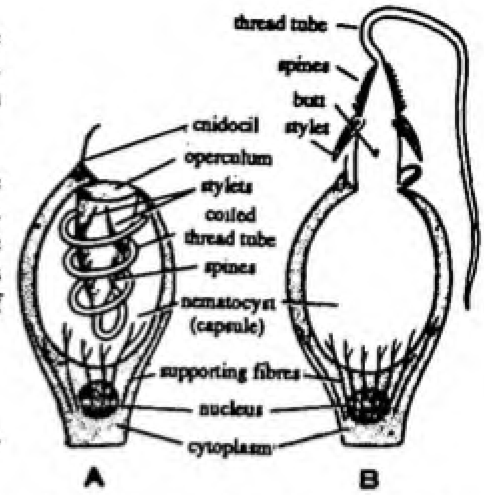


Fig. 24.10 A *cnidoblast*. A—Undischarged B—Discharged.

Mechanism of discharge of nematocyst

The mechanism of the discharge of the nematocyst is not yet fully understood. There are many views regarding it.

1. According to the old view, the nematocyst discharged because of the increase in pressure on the fluid of the capsule.
2. According to *Iwanzoff* and *Yanagita* and others, some amount of the cytoplasm of the nematoblast diffuses into the capsule and increases the pressure of its fluid due to which the nematocyst discharges.
3. According to *Jones* (1947), the nematocysts is always in a state of tension and with stimulation of the cnidocil, the operculum opens and due to its own force of tension the nematocyst discharges automatically.
4. Recent researches have shown the presence of a substance called adenosine triphosphate (A.T.P.) inside and outside the nematocyst which indicate that probably this substance plays important role in the mechanism of the discharge of nematocyst.

Kinds of Nematocysts. Nematocysts are of four kinds:-

1. Penetrant or Stenotele.
2. Volvent or Desmonemes.
3. Streptoline glutinant or Holotrichous isorhizas.
4. Stereoline glutinant or Atrichous isorhizas.

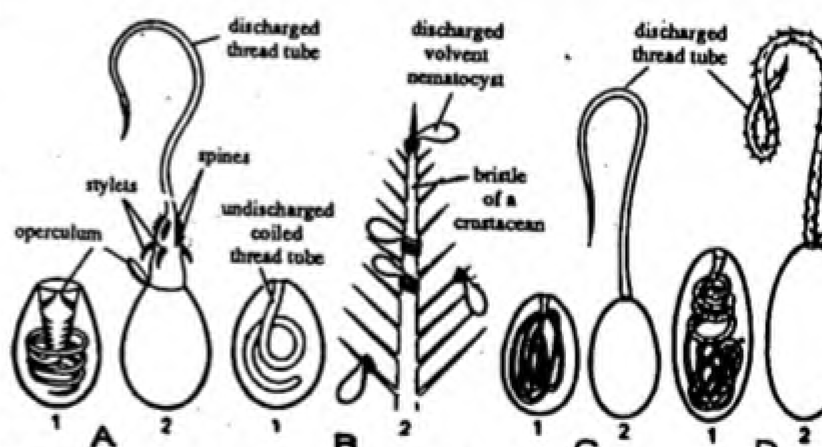


Fig. 24.11 Kinds of *nematocysts*. A—Penetrant, B—Volvent, C—Stereoline glutinant, D—Streptoline glutinant. 1—Undischarged. 2—Discharged

Penetrant. This kind of nematocyst is large and spherical. It is about 0.13mm. long and .007 mm. thick. It occupies the entire cnidoblast, in which it lies. Before being discharged, it is pear-shaped. The thread-tube, which is situated inside it, is coiled transversely. At its base are found three large and three small rows of spines or thorns. When discharged, it pierces the body of the prey and injects the *hypnotoxin* by which the prey is paralysed.

Volvent. This kind of nematocyst is relatively small and pearshaped. It has in it a short thread-tube, which is coiled in a single loop, when the nematocyst is discharged its short thread-tube coil around the hairs of the prey.

Streptoline glutinant. This type of nematocyst is large, cylindrical and pointed at the ends, where thread is discharged. The thread-tube is longer than that of the volvent and is rolled in three or four transverse coils. It posses a spiral row of minute thorns and it twists and coils upon discharging.

Stereoline glutinant. This type of nematocyst is the smallest. Its shape is oval and it possesses thread-tube, which is discharged straight, and is without any barbs or thorns.

The nematocysts are most common on tentacles where all their four types are present while hypostome has only large glutinant type of nematocysts. The rest of the body has only large glutinant and stereoline types of nematocysts. The discharge of nematocysts is not under the control of the nervous system but they are independent effectors. Even nematocysts removed from the body of *Hydra* will shoot out their thread if an adequate stimulus is applied.

An epitheliomuscular cell of a tentacle contains a group of nematocysts, each in its own cnidoblast. Such a group of nematocysts is called a *battery*. There may be as many as 12 nematocysts in a battery and these include 1 or 2 stenoteles surrounded by desmonemes and isorhizas.

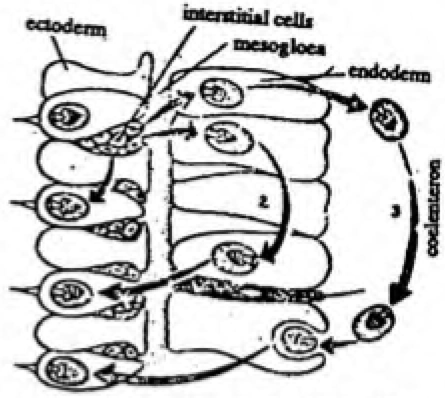


Fig. 24.12 Movement of *nematoblast*.

The cluster of various cnidocytes possessed by a cnidarian are referred to as the *cnidom* and are very useful in classifying the species. A total of eighteen types of nematocysts have been described. The distinctions amongst them is mainly in the character of their tubular thread; in one type the tube is closed at the tip, in the other, it is open. Nematocysts with closed threads are called *astomocnidae*, others with open threads are called *stomocnidae*.

Mesogloea. Mesogloea or mesolamella is a non-cellular, thin layer lying between the epidermis and gastrodermis. It is attached to both the layers. It is secreted by gastrodermis and extends in the entire body and tentacles being thickest in the stalk and thinnest in the tentacles so that the pedal region is able to withstand great mechanical strain and provide flexibility to tentacles. The mesogloea gives rigidity and support to the body and acts as a sort of elastic skeleton.

Gastrodermis. The gastrodermis is the inner layer of the body wall which surrounds the bag-like gastrovascular cavity. It forms about two third of the entire thickness of the body wall. Its structure is almost similar to that of epidermis and is formed a large, often vacuolated and flagellated or amoeboid columnar cells. It is mainly secretory, digestive, muscular and sensory in nature. The following type of cells are present.

(i) *Nutritive muscular or digestive cells.* These cells are almost similar to the epithelio-muscular cells of epidermis. They are long and club-shaped, their outer ends have two processes containing myonemes which do not branch. The myonemes lie at right angles to the long axis of the body and form a circular muscle layer by which the animal contracts and slowly expends the body. A few of these cells serve as sphincters to close the mouth and cavities of tentacles. These cells are best developed in the hypostome and the bases of tentacles. They are highly vacuolated and contain food vacuoles, the free ends usually bear two flagella. The nutritive cells may also secrete digestive enzymes into the coelenteron for the digestion of food. The whip-lik flagella keep the liquid food inside the body cavity in motion. The cells may also give out blunt pseudopodia to engulf food particles.

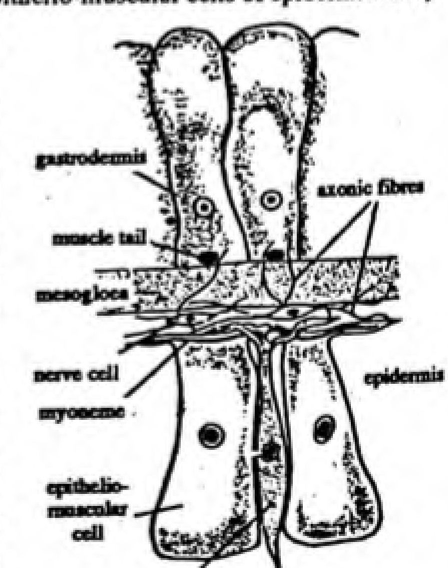


Fig. 24.13 *Neuro-sensory system.*

The ultrastructure of the cells shows that the free end is produced into microvilli and two or more flagella. The latter extend into the gastrovascular cavity and contain 9+2 pattern of fibres. The cytoplasm includes a large number of mitochondria, glycogen granules, secretory granules and food vacuoles. The endoplasmic reticulum and free ribosomes are present in abundance. Centrally placed-nucleus has one nucleolus. The small Golgi complex lies close to the nucleus. The ultrastructure of digestive cells suggests that the cells of stomach, and hypostome serve for ingestion and digestion.

(ii) *Endothelio-gland cells.* The endothelio-gland cells are smaller than the nutritive-muscle cells and occur interspread among the nutritive-muscle

cells. They lack muscle tails at their tapering basal ends but bear one or two flagella at their free ends. The endothelio-gland cells are of two types. The *enzymatic gland cells* secrete digestive enzymes, which are poured into the enteron for extracellular digestion. In the region of hypostome and mouth are found *mucous gland cells*, which secrete a slimy fluid serving as a lubricant and also for entangling and paralyzing the prey. Gland cells are absent in the tentacles and the pedal disc. They are independent effectors as they are not controlled by the nervous system. They are believed to develop from interstitial cells.

(iii) ***Interstitial cells.*** A few interstitia cells occur between the endothelio-nutritive-muscle cells. These are *totipotent* as they give rise to gland cells, sensory cells, reproductive cells and nerve cells.

(iv) **Sensory cells.** The sensory cells are also found in the gastrodermis. They are supposed to be stimulated by the entry of the prey into the gastrovascular cavity.

(v) **Nerve-cells.** There is a net-work of nerve-cells with long processes found in the ectoderm or epidermis in close contact with mesogloea they also form the network in the endoderm. Each nerve-cell consists of a cell having a nucleus. The body of the cell is elongated in the form of fibres, which anastomose to form a network known as nerve-net. Some nerve-fibres are connected with misculo-epithelial cells, while others are in relation with receptor cells.

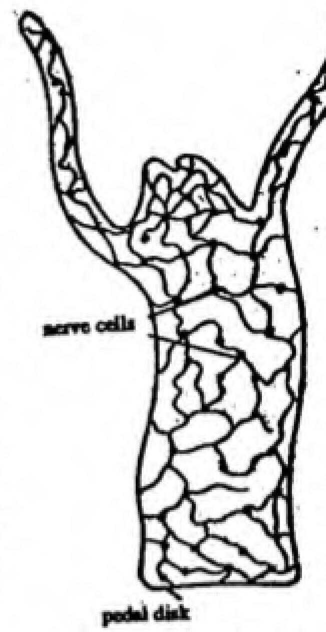


Fig. 24.14 Nerve-net of *Hydra*.

By the type of arrangement of nerve-net, strong stimulus is carried to every part of the body. If tentacles are stimulated, not only the tentacles but also the whole body contracts. This system, although resembles with the *telephone system*, yet is not an efficient one.

Nutrition.

Food. *Hydra* is a carnivorous animal; it eats large quantities greedily. Its food is cyclops, small crustaceans, insect-larvae, annelids etc. Some large specimens of *Hydra* engulf also young fishes and tadpoles, and can take even pieces of meat artificially. *Jennings* recorded a case in which *Hydra* engulfed a catterpillar, which was approximately fifty times the size of the *Hydra*. Usually, *Hydra* captures food of smaller size.

Hydra remains attached to the basal disc and its body and tentacles are fully extended in water. Thus, it covers a larger territory for hunting its prey. As soon as tentacles come in contact with prey or food-material, stinging cells or nematocysts are projects, which sting the prey. With the help of poisonous secretion, known as hypnotoxin, the prey is paralysed. Once, the prey gets entangled in the tentacles, it cannot escaped due to the viscid surface of the tentacles.

Sometimes, when *Hydra* is very hungry, it dips into the water and fills the gastrovascular cavity with the ooze.

Ingestion. Coelenterates are the first animals to use projectiles, called *nematocysts*, for capturing animals. The volvents coil around bristles and other appendages on the prey, while the glutinants fasten to its surface, thus holding it fast. The penetrants puncture the victim and inject the paralyzing fluid or *hypnotoxin*. Other tentacles may also perform coordinated movements and shoot their batteries of nematocysts. The tentacles, holding the prey, now contract and bend inward drawing the paralyzed prey towards the mucus-lined mouth, which opens widely to swallow it. Mucous secretions help in swallowing and the mouth can be greatly distended. Contractions of the hypostome and body wall (peristaltic movements) force the food down into the gastrovascular cavity where digestion takes place.

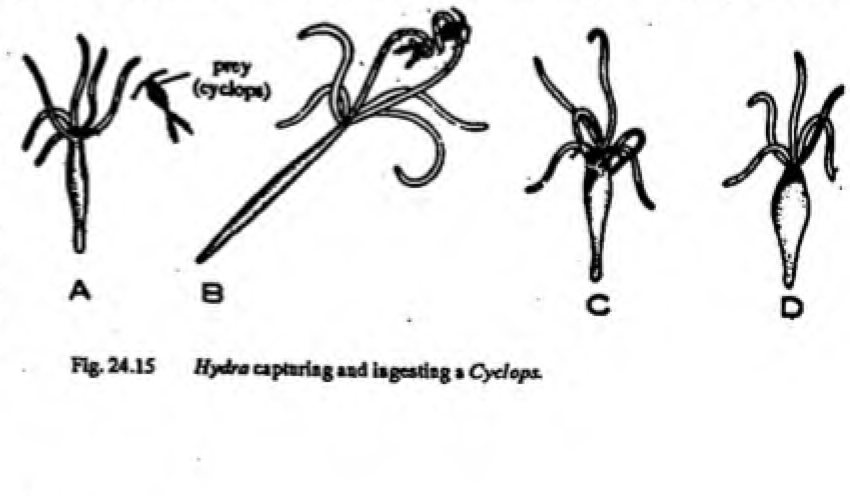


Fig. 24.15 *Hydra* capturing and ingesting a *Cyclops*.

The food reaction varies greatly according to the state of the animal. A very well-fed *Hydra* will not react to food when it is presented, while a hungry *Hydra* will respond even when a chemical stimulus, such as beef juice, is added to the water. A chemical, called *glutathione*, usually found in the tissue fluids of most animals, is necessary to evoke feeding reaction. Thus, *Hydra* engulfs only those animals which have glutathione in their body.

Digestion. The digestion of the prey occurs in two stages. First, the prey is killed by the action of the digestive juice secreted by the gland cells of the gastrodermis. The churning movements caused by the expansion and contraction of the body wall and the lashing movements of flagella of the nutritive muscle cells thoroughly mix up the digestive juice with the food which is broken into smaller particles suspended in a meaty broth. The digestive enzymes react upon the disintegrating food. The proteolytic enzyme similar to trypsin partly digests the proteins into polypeptides. The tissue of the prey turns into a soupy broth. This type of digestion, occurring in the cavity, outside the gastrodermal cells is called *extracellular digestion.* It also takes place in the stomach and intestine of most multicellular animals like frog, earthworm, etc. It is met with in *Hydra* for the first time.

Smaller fragments of food are then engulfed by the nutritive muscle cells by means of pseudopodia and digested within food vacuoles, where *intracellular digestion* occurs, as in Protozoa and Porifera, but unknown in the vertebrates. Within food vacuoles the further digestion of proteins and fats takes place. Studies have revealed that the food vacuoles undergo both acidic as well as alkaline phases, Digestion in *Hydra*, therefore, is quite interesting, since it combines the digestive procedures of forms both lower (Protozoa) and higher (Vertebrates) than itself. In this respect *Hydra* holds an intermediate position between the Protozoa on one hand and the higher Metazoa on the other. The retention of intracellular digestion is probably due to its aquatic mode of life, as the digestive juice gets diluted in the gastrovascular cavity.

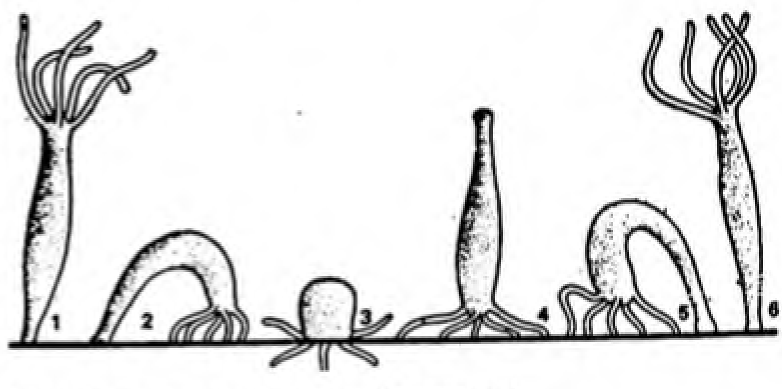


Fig. 24.16 *Hydra* showing saumersaulting movement.

Distribution. Absence of circulatory system offers no difficulty in the distribution of digested food. Contractions of the body-wall and lashing of gastrodermal flagella circulate the products of digestion in the cavity, which is continuous throughout the body. It is because of its dual (digestive and circulatory) function that the cavity is termed the *gastrovascular cavity.* From the cavity, the digested food is absorbed into the gastrodermal cells. From here, some of it diffuses through the mesogloea into the epidermal cells. Certain gastrodermal cells, after capturing the food-particles, break off from their neighbouring cells and either move in an amoeboid manner or are carried passively by currents set up by the flagella into the tentacles where they are ingested. Even fragments of gastrodermal cells also distribute the food in a similar way.

Assimilation. The food absorbed into the cells is transformated into protoplasm. A part of the food, especially the oil globules, is stored in the epidermal cells for use in the production of energy.

Egestion. The indigestible residues are cast off by gastrodermal cells into the enteron. From here, they are expelled out through the mouth by a series of violent contractions of the body-wall. The debris falls some distance away from the animal.

Locomotion

Hydra is mostly attached by the basal disc to some suitable object in the water. While stationary, the body and tentacles twist and move in various directions to capture food. But they also show actual movement from one place to another. They perform movement either in response to light or some chemical stimulus or in

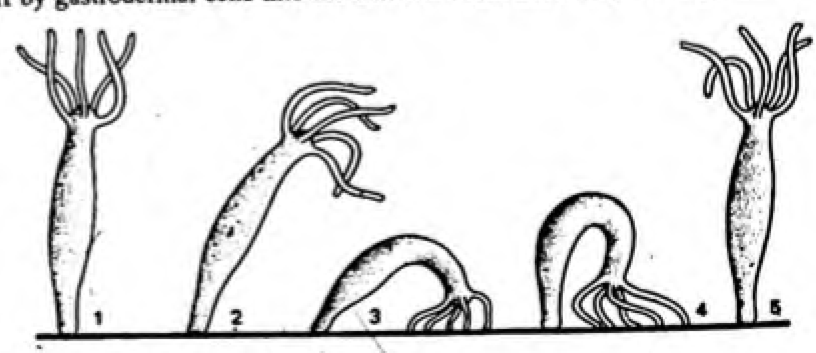


Fig. 24.17 *Hydra* showing looping movements.

search of food. The contraction and expansion of the contractile muscle fibres of epidermis bring about locomotion. The following types of movements are found in *Hydra*:

(i) **Expansion and contraction.** *Hydra,* when hungry, remains attached to a substratum in water and frequently expands and contracts itself at intervals. This movement is performed to bring food particles in contact with the tentacles which are waved all around in water. Also, contraction of one side and elongation of other side of the body or tentacles result in the bending and swaying movements which assist in the capture of prey.

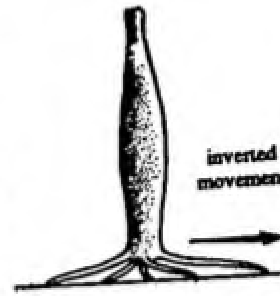


Fig. 24.18 *Hydra* showing cuttle-fish like movement.

(ii) **Somersaulting.** This type of locomotion resembles the looping type of locomotion. The body bends in the direction in which it has to move in the same manner as in looping locomotion. The tentacles take a firm hold of the substratum and the basal disc is released. The body now straightens up in such a manner that the animal stand up side down, *i.e.* the oral end with its tentacles holding the substratum and the released basal disc pointing upwards. The body now bends once again in the forward direction so that the basal disc touches and then becomes fixed up to the substratum ahead of the oral end. The tentacles release their hold on the substratum and the animal regains its erect position, *i.e.* basal disc attached to the substratum and oral end with its tentacles pointing upwards.

(iii) **Looping.** *Hydra* can also move from place to place in search of food. Usually the body first extends and then bends over, so that the tentacles attach to the substratum with the help of adhesive glutinant nematocysts. Then the pedal disc is released and brought up closer to the circlet of tentacles and attached. The tentacles now loosen their hold and the body becomes erect again. The whole process which is repeated again and again appears like a series of looping movements of a caterpillar or leech.

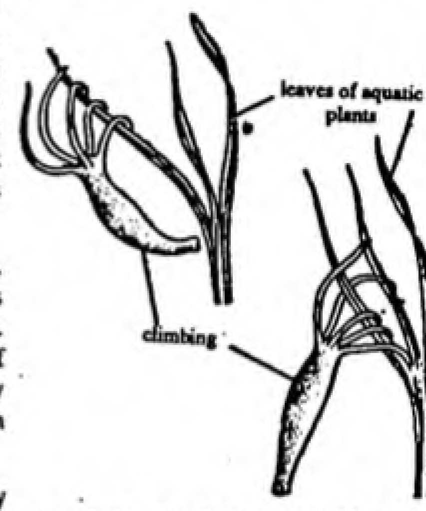


Fig. 24.19 *Hydra* showing climbing.

(iv) **Gliding.** Provides only small and slow movement along its attachment by alternate contraction and expansion of basal disc. It is brought about by creeping amoeboid movement of the cells of the pedal disc which gives out pseudopodia like projections. The animal can, sometimes, creep considerable distance by this method.

(v) **Walking.** Occasionally, *Hydra* becomes inverted and stands on its tentacles and moves in an inverted condition, using its tentacles as if they were legs. This type of movement takes place on some object such as leaf and in leisurely hours.

(vi) **Climbing.** While changing location in a limited area, *Pelmatohydra oligactis*, can even climb by attaching its long tentacles to some object, releasing the foot, and then contracting the tentacles, so that the body is lifted up the object.

(vii) **Floating.** Very often *Hydra* exhibits the floating movements. The cells at the basal disc release large bubble of gas in mucus which helps the animals to float and rises to water surface.

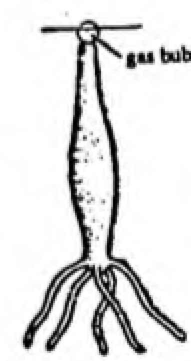


Fig. 24.20 *Hydra* showing floating

(viii) **Surfacing.** Sometimes, *Hydra* uses a gas bubble secreted in mucus by the cells of the pedal disc, to rise in water and float at the surface. If the gas bubble bursts, the mocous threads substance the body on the water surface due to surface tension.

(ix) **Swimming.** It is said that sometimes the animal frees itself from the substratum and swims in water by the undulating, wave-like movements of the tentacles and the body.

GROWTH

Growth in *Hydra* involves the division of all types of cells except the cnidoblasts. The latter are formed from the interstitial cells. The growth chiefly takes place just below the bases of the tentacles. From this growing region, new cells are added either

towards the tentacles or towards the basal disc. Old cells are constantly sloughed off from the basal disc and tips of the tentacles to be replaced by new ones pushed down from the growing region. Under normal conditions this process continues indefinitely. For this, *Brien* and others consider *Hydra* to be immortal.

RESPIRATION AND EXCRETION

There are no special respiratory and excretory organs in *Hydra*. Respiration and excretion are only possible by the general surface of the body. Oxygen diffuses into the cells from water and carbon-dioxide passes out of the cells. Nitrogenous waste products are also removed by the general surface of the body.

BEHAVIOUR

Reaction to the stimuli in *Hydra* is affected by contact, reaction to the chemicals, reaction to temperature-changes and reaction to light.

(a) Trigmotropism (reaction to contact). By non-localized stimulus *i.e.*, the one which affects the animal as a whole, *Hydra* responds by withdrawing tentacles and by contraction of the body. But if there is a localized stimulation, the response to the stimuli will be in the area affected, which may cause withdrawal of a single tentacle or bending of the whole body.

(b) Chemotropism (reaction to chemicals). The response to chemicals is due to the nature of the chemicals. The *Hydra* avoids injurious chemicals. It responds positively to the presence of food. In food taking reaction, both chemotropism and thigmotropism are involved.

(c) Phototropism (reaction to light). *Hydra* moves towards optimum light by the *trial and error method.* Green *Hydra* moves towards intense light.

(d) Thermotropism (reaction to temperature). *Hydra* become active in the water, kept at a temperature approximately 31oC. They flourish in cool water. *Hydra* are also found in abundance under ice in winter but do not survive in a temperature raised in a shallow pool by exposure to summer sun.

(e) Periodic contraction-bursts. This is a characteristics feature of the behaviour pattern, by which the animal contracts so as to form a tight ball. The contractions are followed by extensions, which take place every five to ten minutes in day-light. However, the frequency becomes much less at night *McCullogh* (1963) pointed out that these bursts serve for regular intermittent sampling of the environment around the *Hydra*.

REPRODUCTION

Hydra reproduces asexually as well as sexually. Asexual reproduction is more common than the sexual reproduction, secondly asexual reproduction takes place during favourable condition whereas sexual reproduction takes place during unfavourable circumstances.

1. **Asexual reproduction.** It takes place in the following three ways:

(a) Budding

(b) Grafting

(c) Fission

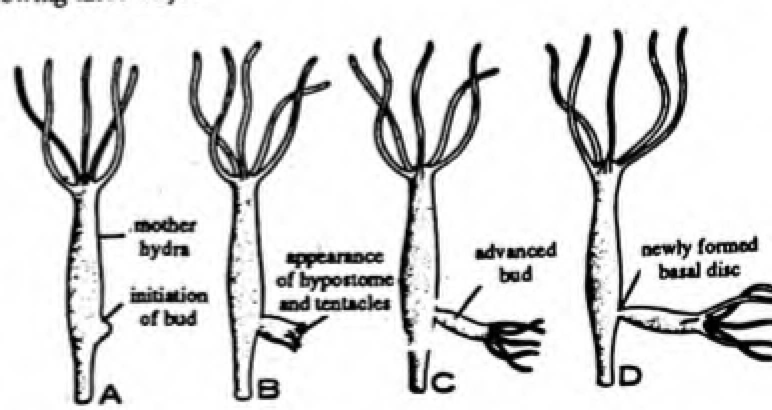


Fig. 24.21 Budding in *Hydra*

(a) ***Budding.*** *Hydra* reproduces by this method under favourable conditions i.e. when food is available to it in plenty and the temperature of the water is also suitable. During this process, the nutritive substances start accumulating in the ectodermal cells of its body. Small projections appear in its body by repeated divisions of the ectodermal cells in

these regions. These projections are called *buds*. Ectoderm and endoderm both take part in their formation. These are hollow and connected with the gastrovascular cavity. These gradually grow and in the end become narrow tube-like. Their internal and external structures both are like the parent *Hydra*. The tentacles are present at their free ends. The mouth is surrounded by these tentacles. The bud starts constricting at the place where it is attached to the parent body and gradually separates from the parent to become a young *Hydra* which performs all its life activities independently. Sometimes, these buds do not separate from the parent *Hydra* and remain attached to it. Thus they give rise to a branched *Hydra*. If the favourable conditions continue to exist then *Hydra* goes on increasing its species by this method of budding.

(b) ***Grafting.*** The grafting in *Hydra* has been in the same way as it is done in plants. This method has been successfully used in *Chlorohydra viridissima*. Two such hydras are taken. One of these is kept in dark so that its chlorophyll decomposes and it becomes white in colour. Now this white and the other green *Hydra* are both cut transversely through the middle by a sharp knife. The lower half of the white *Hydra* is attached to the upper half of the green *Hydra* and the remaining two halves are also attached to each other. After some time, the white and green halves fuse to form a *Hydra* which reproduces by budding. The buds which arise at the junction have their upper part green and lower part white.

(c) ***Fission.*** Sometimes, the body of *Hydra* constricts transversely or longitudinally into two parts. Each part forms the necessary organs and develops into a complete *Hydra*.

(2) **Sexual Reproduction.** In *Hydra*, the sexual reproduction takes place under unfavourable conditions. Whenever these is lack of food and oxygen or the temperature becomes much high or low then the reproductive organs start forming in *Hydra*. These animals are bisexual and the development of reproductive organs takes place from the interstitial cells. The reproductive organs are different from buds chiefly in two respects. (1) ectoderm and endoderm both are present in buds but endoderm is absent in reproductive organs (2) the buds are hollow with an internal cavity but the reproductive organs are solid. In *Hydra*, the reproductive organs are formed only during the breeding season and they disappear after it. Their breeding season extends from the end of rainy season to the beginning of the winter.

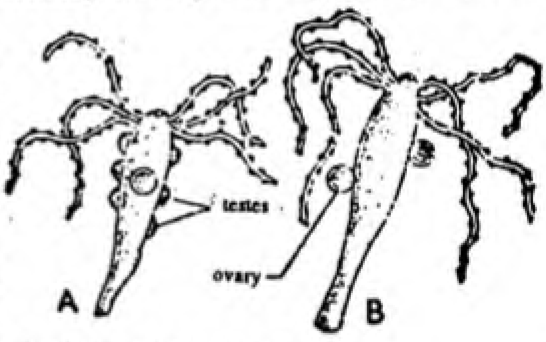


Fig. 24.22 Male and female *Hydra*

Testes. They are formed in the upper part of the body and are cone-shaped. The *interstitial cells* of the testis divide repeatedly to form *sperm mother cells* or *spermatogonia*. Each sperm mother cells divides twice and changes into *primary spermatocytes*. The spermatogenesis now takes place in each spermatocyte during which it divides by two maturation divisions.

The first division is *meiotic* and the second in *mitotic*. As a result of these divisions, four *spermatids* are formed from each spermatocyte. Later, the *tailed sperms* are formed from the spermatids by *spermatogenesis*. Thus many sperms are formed in testis.

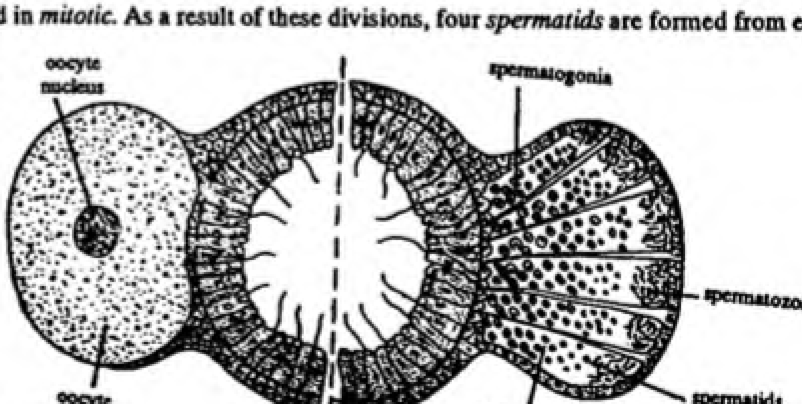


Fig. 24.23 Transverse section through the body of *Hydra*—on the left through on ovary and on the right through a testis.

When the number of sperms becomes large, they exert pressure on the wall of the testis, which ruptures at its knob-like part called *nipple* and the sperms are released in the water where they swim freely with the help of their tails.

Ovaries. They are formed in the lower part of the body of *Hydra*. There are many *interstitial* cells in each ovary. One of these cells, called oocyst, becomes larger and amoeboid with a big nucleus is seen. After some time, two divisions take place in this cell. The first division is meiotic and the second is mitotic. Thus in each ovary, an ovum and two *polar bodies* are formed. When the ectoderm over the ovum ruptures by contraction, it forms a cup-like cushion around the ovum which becomes implant at that place in a protruding condition. This

state is known as protendrous condition. This is the reason why cross fertilization does not occur in *Hydra*. The fully matured ovum must be fertilized within 24 hours of its becoming exposed in the water otherwise it would become useless and dies.

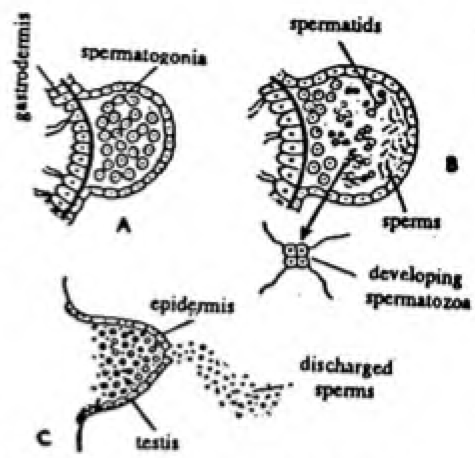


Fig. 24.24 A, B—Ripening of a testis in *H. oligactis*, C—in *H. littoralis*.

At the time of fertilization the ovum attracts the sperms or spermatozoa towards itself. Only one sperm penetrates the ovum. The head alone of the penetrating sperm enters the ovum and the tail is left outside. After this the nucleus of the sperm fuses with the nucleus of the ovum and a diploid *zygote or oospore* is formed.

CLEAVAGE AND DEVELOPMENT

Zygote, still stated in the epidermal cup cover its mother, undergoes segmentation or cleavage. Within a short time, zygote is transformed into a hollow *blastula or coeloblastula*, cell of which, the *blstomeres*, are all equal in size and surround a fluid-filled, cavity, the *blastocoel*. Later, as blastomeres multiply by quick divisions, some cells leave the surface and migrate by *primary delamination* into the interior from all directions (*multipolar ingression*), and obliterate the blastocoel. The embryo is now known as a *gastrula*. A new cavity or space develops in the gastrula, this is surrounded by the cells that migrated into the interior and is called archenteron. So the gastrula has two layers of cells, an outer, the *ectoderm*, and an inner, the *endoderm*. Meanwhile, ectoderm cells have been secreting a chitinoid spiny *cyst* or *theta* around the embryo. The encysted embryo is detached from the parent body and falls to the bottom. Ponds may dry up and cysts blown off by the wind or carried by water-birds on their feet and breaks from one pond to the other.

HATCHING

The encysted embryo remains dormant and unchanged for several weeks, until the next spring. As it can withstand drying and freezing, it carries the race through droughts and winters. It is also probable that this resting stage serves for dispersal, for its can be carried by currents of wind, or in mud on the feet of animals to other ponds in which water is present.

With the advent of favourable conditions of water and temperature development is resumed. *Interstitial cells* arise in the ectoderm and *mesogloea* is secreted between the two cellular layers. The embryo elongated, and a circlet of tentacle buds develop at one end with a mouth appearing to their midst. As the embryo increases in size, the outer cyst wall softens to break open and the embryo hatches into a partially differentiated polyp. There is no free larval stage in the development of *Hydra*. This life-history of *Hydra*, thus, has the scheme: polyp--egg-- polyp.

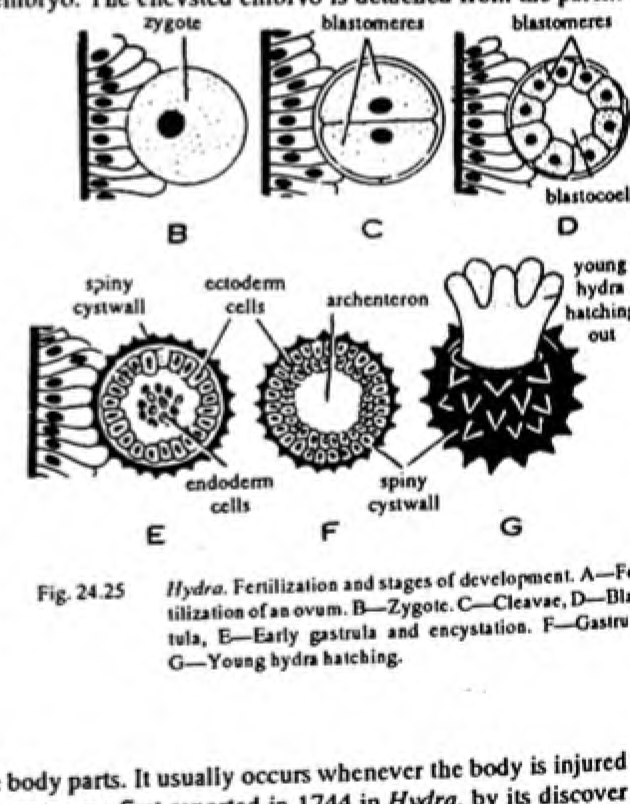


Fig. 24.25 *Hydra*. Fertilization and stages of development. A—Fertilization of an ovum. B—Zygote. C—Cleavae, D—Blastula, E—Early gastrula and encystation. F—Gastrula, G—Young hydra hatching.

REGENERATION

Regeneration is the ability of an organism to replace its damage body parts. It usually occurs whenever the body is injured or can also be induced artificially by mutilation, the power to regenerate was first reported in 1744 in *Hydra*, by its discover *Abraham Trembly*. Regenerative power also occur in many other coelenterates and other invertebrates, but *Hydra* alone has been a favourite material for experimentations.

A. Trembly (1744) found that if a living *Hydra* is cut across into two, three or smaller, *Hydra*, provided the pieces are not too small. A fragment of *Hydra*, measuring 1/6 mm. or more in diameter, is capable of regenerating an entire individual. Although regenerating results in an increase in number, it is not reproduction because it is not a normal method of multiplication.

Regeneration of *Hydras* is made possible by the amazing generative powers of the totipotent interstitial cells.

One characteristic feature of regenerating piece in *Hydra* is that it retains *polarity*. The end nearer the mouth develops mouth and tentacles, while the end nearer the base forms a new base.

Parts of one *Hydra* may be easily grafted upon another provided they are of the same species. Grafting can be done in various arrangements producing many bizarre effects.

A. Trembly observed if the head end of a *Hydra* is split in two and the parts are separated slightly, it results into a Y-shaped specimen, or "two-headed" individual, having

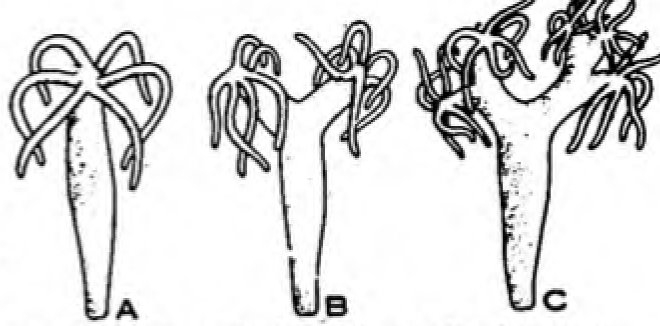


Fig. 24.26 *Hydra* showing the formation of multiheaded specimen by regeneration. A—Single heade *Hydra*, B—Two headed *Hydra*, C—Four headed *Hydra*

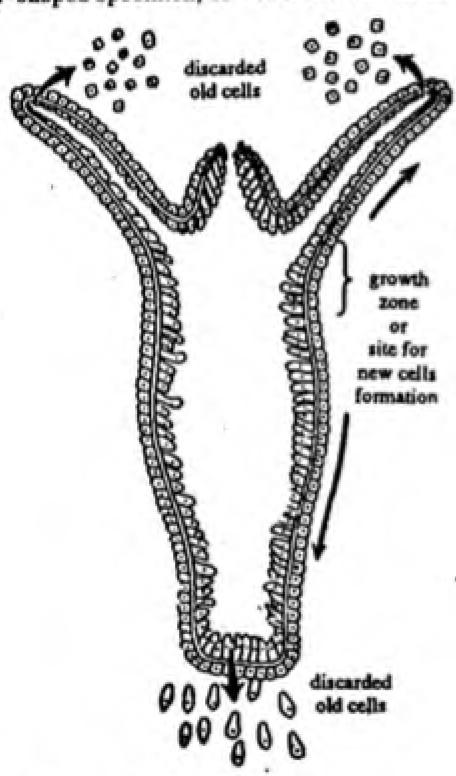


Fig. 24.27 Cell replacement in *Hydra*

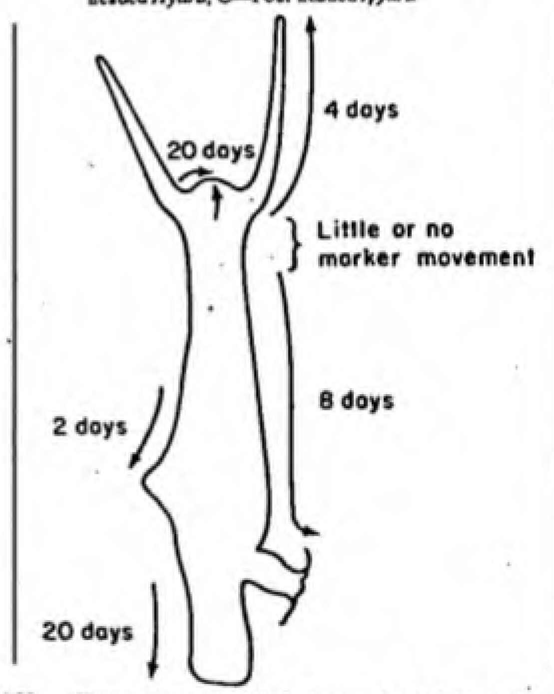


Fig. 24.28 Tissue movement in *Hydra* as a result of mitotic activity. Arrows indicate direction of movement and numbers indicate days required for cells to movement and numbers indicate days required for cells to move along path of arrow

two mouths and two sets of tentacles. Each head may be again split in a similar manner. Thus, *Trembly* succeeded in producing a "sever-headed" *Hydra*. It was the great regenerative power of these animals which won for them the name "*Hydra*", after a Greek mythological monster which was finally destroyed by Hercules. According to the legend, 'Hydra' had nine heads and sooner did Hercules cut one off, than two grew in its place.

IMMORTALITY IN *HYDRA*

The *immortality of Hydra* has been deseubed by *P. Brien* 1955. According to him there is a *growth* zone just below the tentacles where interstitial cells give rise to all other cell of the body. With the formation of new cells, old cells are pushed towards the end of the tentacles and the pedal disc, from where they are shed to outside. In about 45 days, the older body cells are replaced by new cells. This process of cell replacement is an endless process. It has also been shown that, if the interstitial cells of the growth zone are destroyed, the *Hydra* lives only for a few days.

25

OBELIA

The structure of other coelenterates is more complex than that of *Hydra*, therefore, its structure can not be considered as typical of coelenterates. *Hydra* is a fresh water animal whereas most coelenterates are marine and colonial. Their life cycle is more complex then that of *Hydra*. *Obelia* is commonly studied as a typical example of marine and colonial coelenterates. Many species of *Obelia* are found but the most common is *Obelia geniculata*.

SYSTEMATIC POSITION

Phylum	-	Coelenterata
Subphylum	-	Cnidaria
Class	-	Hydrozoa
Order	-	Hydroidea
Sub-order	-	Leptomedusae
Genus	-	*Obelia*

HABITS AND HABITAT

Obelia is a tree-like branched, marine colonial hydroid coelenterate growing on the surface of sea-weeds, rocks and pilings along the sea-coasts. Colonies appear like whitish or light-brown branched threads, about 30 mm. to several cms in height. The colony arises by budding from a single hydra-like individual, the buds fail to separate and after repeated budding there results a tree-like growth permanently fixed to some object and consisting of numerous members joined to the main stem. The members are known as *zooids*.

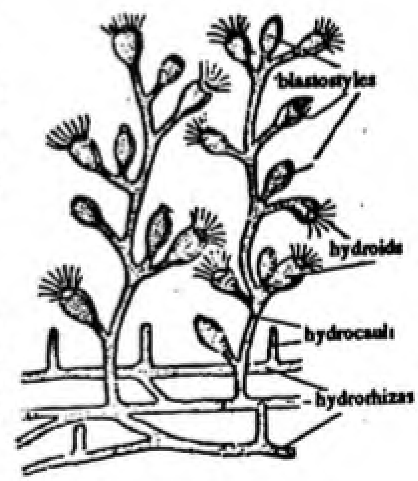


Fig. 25.1 *Obelia* colony.

EXTERNAL MORPHOLOGY

If a colony of *Obelia* is examined under low power of microscope, it is found to be made up of a root-like horizontal part resembling a basal stem, called *hydrorhiza* which is attached to the substratum. From the hydrorhiza grows an upright stem called *hydrocaulus* (plural-hydrocauli). Hydrocaulus and hydrorhiza consist of two distinct layers.

(a) **Perisarc.** It is transparent, tough outer layer, yellow in colour, of horny consistency. It is not composed of cells but is a cuticular secretion of the ectodermal cells. The *perisarc* is tubular in shape and is at first in contact with the ectoderm but after wards becomes separated from it by a small space, except at regular intervals. This condition is acquitted secondarily, as during its formation it is in contact with ectoderm but, when it thickens, ectoderm withdraws except at some places. In some parts, perisarc is ringed. Perisarc serves as a protective layer and gives support to the branches having zooids.

(b) **Coenosarc.** Fibrous processes connect the perisarc with coenosarc. It is an inner, granular layer. It is hollow and its tubular cavity is continued into cavities of polyps, thus, forming a part of *gastrovascular cavity*. There is a fluid, which shows flickering movement similar to that of cilia. Coenosarc consists of an outer layer, the *ectoderm* and an inner layer, the ***endoderm***.

From the upright stem, called *hydrocaulus*, several side-branches arise. These side-branches are ringed and their end is expanded into a hydra-like structure known as *hydranth* or *polyp*. Hydranth is a kind of *zooid*. Towards the proximal region of the colony are found cylindrical bodies known as *blastostyles*. These give rise to several small lateral offshoots, called *medusa buds*.

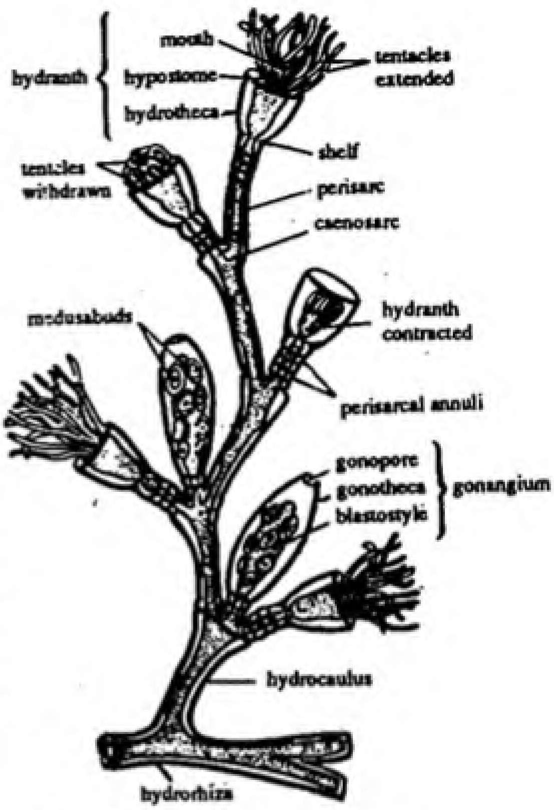


Fig. 25.2 *Obelia*. A part of colony under the microscope.

Thus, *Obelia* colony is *trimorphic*, having

(a) **Polyp or hydranth,**

(b) **Blastostyle, and**

(c) **Medusa.**

Polymorphism

Due to the presence of three types of zooids or the individuals the *Obelia* colony (trimorphic) is said to exhibit the phenomenon of polymorphism which is correlated with the colonial organization of *Obelia*. The phenomenon of polymorphism is essentially one of division of labour i.e., different functions are assigned to different individuals rather than to parts of organs of one individual. It may be recalled here that in *Obelia* the feeding zooids (Hydranths), asexually reproducing zooids (Blastostyles), and sexually reproducing zooids (Medusae) perform their respective functions for *Obelia* and thus exhibit division of labour.

Hydranth or Polyp

It is a nutrient polyp which in its essential structure resembles *Hydra* very much. Under the high power microscope, the polyp looks a hollow case of yellowish colour. It is joined to the main branch by a small stalk. At its distal end it carries an expanded cone-like *manubrium* or *hypostome* which measures about one third of the polyp. The *mouth* is situated at the tip of the manubrium. At the base of the manubrium are twenty four solid *tentacles* which are arranged in a circle. The manubrium is hollow; its cavity opens out by mouth while on the other side, it is continuous with the gastrovascular cavity. The mouth is elastic and capable of great dilation and contraction. It serves both for ingestion and egestion, there being no anus in this animal.

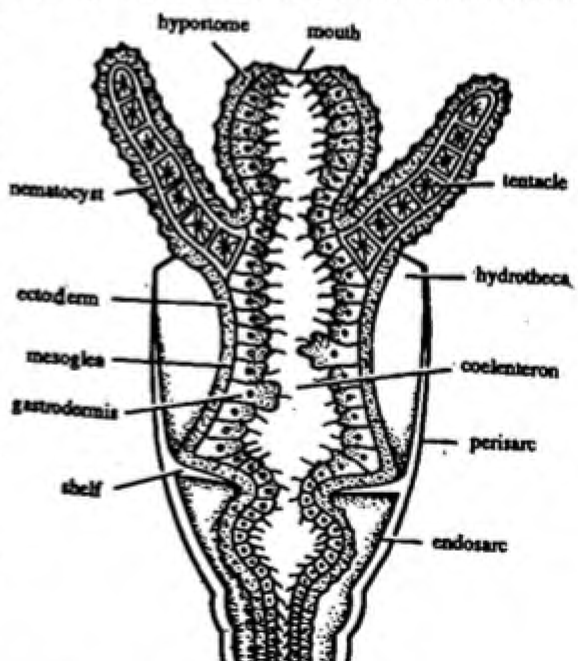


Fig. 25.3 Vertical section of hydranth of *Obelia*

The perisarc, covering the polyp, forms a cup-like structure called the *hydrotheca* which is transparent and perfectly colourless. The hydrotheca forms a sort of circular *shelf* near its proximal end on which rests the polyp. Normally the polyp remains extended out of the hydrotheca but when disturbed the, tentacles and the manubrium contract rapidly and are almost completely withdrawn into the hydrotheca.

Histology

As seen under light microscope in longitudinal section the body wall of the hydranth is seen to consist of two layers of cells:

(a) the outer *ectoderm* or *epidermis*.

(b) the inner *endoderm* or *gastrodermis*,

and separating the two layers is a delicate membrane called *mesoglea* or supporting lamella. The hypostome also consists of these two layers of cells. The layers of polyps are continued as coenosarc. The other zooids are also made up of the same layers described above.

Ectoderm is thin and is made up of columnar epithelium. The cells are conical in shape. Interstitial cells may be present in the space between the narrow ends of ectodermal cells. But according to *Grove* and *Newell* the interstitial cells are completely absent. Nematocysts are also present in the ectoderm which act as organs of offence and defence. The nematocysts are specially abundantly present in the tentacles where they constitute annular batteries.

Endodermal cells are large and glandular and their free ends have pseudopodia or flagella, the movement of the latter cause the entry of food particles into the coelenteron (enteron). Gland cells with granular protoplasm are also present in endoderm. They produce digestive enzymes. Tentacles and hypostome also have a layer of unstriated muscle fibres lying between ectoderm and mesoglea which helps in rapid contraction of tentacles. In hypostome, muscle lying transversely serves to contract the cavity and act antagonistically to the action of longitudinal muscle fibres.

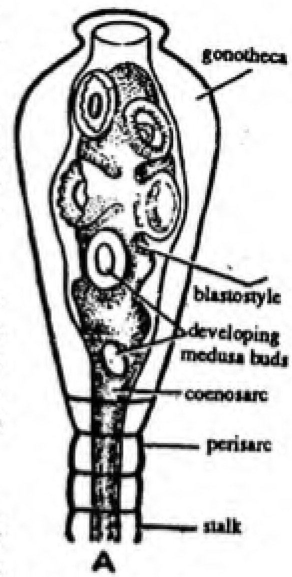


Fig. 25.4 *Entire*

Blastostyle. The blastostyles are developed when the hydrocaulus has attained its full length. They are generally produced on the lower part of the colony in the axil of the branches that bear polyps. The blastostyle is a club-shaped zooid without mouth and tentacles. It is hollow and its cavity is continuous below with that of the rest of the colony. It is enclosed in a cylindrical expansion of the perisarc, the *gonotheca*.

The blastostyles serve to produce the third type of zooids, i.e., the medusae. This occurs by budding. The medusae ultimately get constricted off from the blastostyle and become free inside the gonotheca. The gonotheca develops at its tip an aperture, the *gonopore*, and medusae escape into the sea through it. They are probably expelled through the gonopore by currents produced by rhythmic contractions of the polyps.

The blastostyle, gonotheca and the medusa buds are collectively called the *gonangium* or *gonanth*.

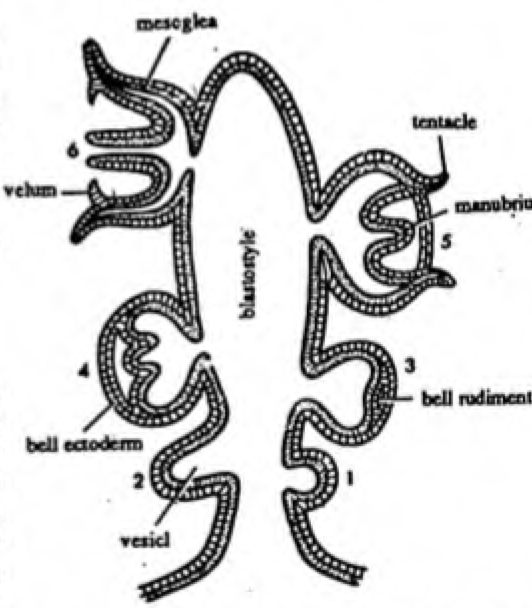


Fig. 25.5 Development of *medusa* from a blastostyle.

PHYSIOLOGY

Nutrition. The polyps are the feeding zooids. They supply food to the entire colony. The food consists of small living organisms. They are captured with the help of nematocysts and brought to the mouth by tentacles as seen in *Hydra*. The annuli round the stalks of the polyps give them sufficient flexibility to move to and fro in water in pursuit of food. A part of the food is digested in the gastrovascular cavity of the polyps by the action of the digestive juices secreted by the gland cells of the gastrodermis. This is called the *intercellular* or *extracellular* digestion. The partly digested food circulates in the gastrovascular cavity of entire colony by beating of the flagella of the gastrodermal cells and by convulsive peristaltic contractions of the polyps. It is ingested from the gastrovascular cavity by the pseudopodia of the gastrodermal cells in which it is digested in much the same way as in *Amoeba*. This is known as the *intracellular digestion*. From the gastrodermis, some of the digested food is passed on to the epidermis by diffusion. The undigestible food is egested through the mouth of the polyp. Starch, cellulose and chitin are not digested. The digested food is supplied to the entire coloney including blastostyle.

Respiration. Respiration is aerobic and occurs through the general surface. The cavity of the entire colony contains water, which enters through the mouth of the polyps. This water is kept circulating by the contractions of the polyps and beating of gastrodermal flagella. The epidermis is also in contact with water which diffuses through the permeable perisarc. Thus, almost all the cells are in contact with water which has oxygen dissolved in it. This oxygen diffuses into the cells and the carbon dioxide

likewise diffuses out of them.

Movements. Colony in incapable of locomotion. Its zooids, particularly polyps, show movements. They can contract and expand their body and can bend their tentacles.

Grov.. :owth of the colony occurs more or less like a plant. It involves spreading of the branches of hydrorhiza along the substr.. development of new hydrocauli from the hydrorhiza and formation of new zooids on the branches arising from the hydro.. It is to be noted that until a polyp is developed at the end of a branch, the latter does not produce the next branch. Blastostyles grow by budding in the axils of the older branches of a full-grown hydrocaulus. The stimulus leading to blastostyle formation is not clear.

Excretion. Elimination of nitrogenous waste materials takes place by diffusion through the general body surface.

Behaviour. The polyps are sensitive to stimuli. They respond to touch and unfavourable chemicals by contraction.

Osmoregulation. The colony has no problem of osmoregulation as the sea-water is almost as dense as the cell contents. As the sea provides almost a uniform environment throughout the year and there is no desiccation, *Obelia* colony does not experience unfavourable periods and is capable of indefinite survival.

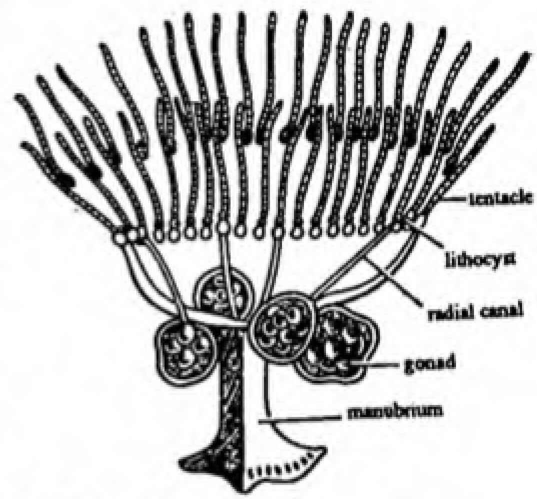


Fig. 25.6 *Obelia*. A medusa in oral view.

MEDUSA

The medusae are the reproductive zooids, some produce eggs and others produce sperms, *i.e.* the sexes are separate. Each medusa, when fully mature is a saucer-shaped structure. The outer convex side is called the *ex-umbrella* while the concave inner side is known as the *sub-umbrella*. The attachment of the medusa with the blastostyle is by the exumbrellar surface. From the centre of the sub-umbrella hangs a process called *manubrium*, which bears four-sided *mouth* at its top.

The *mouth* leads into the enteric cavity which is divided into four *radial canals* running towards the periphery where they open into the *circular canal*. The cavity of the manubrium, the radial canals and the circular canals are all lined by the gastrodermal cells. The food is ingested through the mouth and its digestion takes place in the radial and the circular canals.

The peripheral edge of the umbrella is produced into a narrow inward fold called the *velum*. From the margin of the velum arise a large number of tentacles. In a young medusa there are sixteen tentacles but their number increases in adult medusa. These tentacles, like the tentacles of the polyp, are solid structures having a core of endoderm cells surrounded by ectoderm. There is a definite plan of arrangement of these tentacles around the velum. In the young medusa (when there are only 16 tentacles), they are arranged in four groups, each group having 4 tentacles. The four tentacles placed against the

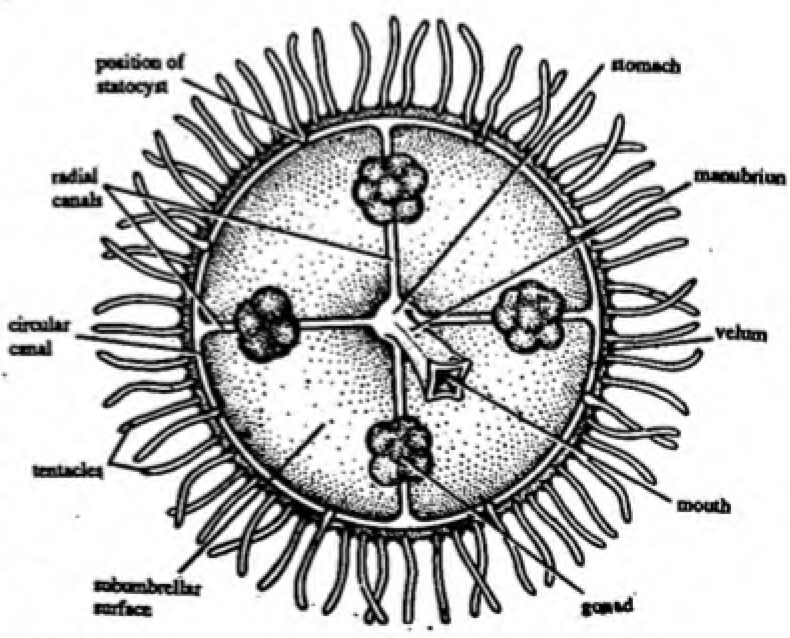


Fig. 25.7 An everted *medusa*.

four radial canals are the *per-radial tentacles.* Bisecting the four angles between the per-radials, are the four inter-radii having the *inter-radial tentacles.* The radii bisecting the inter-radii are the *ad-radii* having the *ad-radial tentacles.* Thus there are four per-radial, four inter-radial and eight ad-radial tentacles.

At the base of eight ad-radial tentacles, a few interstitial cells get collected. These cells form a sort of reservoir of cells which form the statocysts. In the basal part these cells contain calcareous particles, *otoliths* or *otocysts.* These cells are also provided with hair-like processes of sensory cells. These organs were previously supposed to be auditory organs. Now they are thought to be co-ordinating or balancing organs which help to maintain the equilibrium.

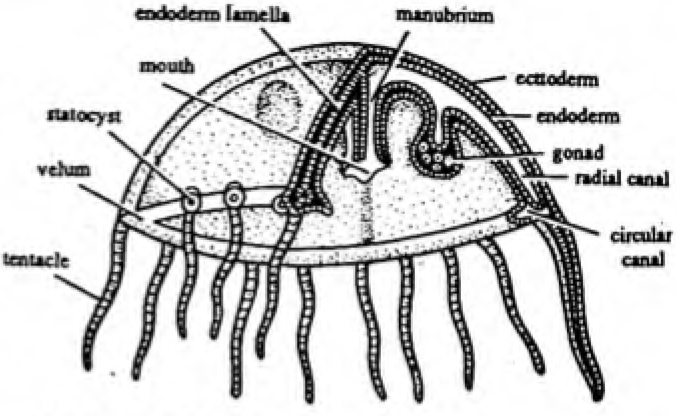


Fig. 25.8 *Medusa* in section.

Histology. Microscopically the structure of medusa resembles that of the hydranth polyp. It consists of the outer epidermis and inner gastrodermis with mesogloea in between the two. At the tip of the manubrium the gastrodermis is continuous with the epidermis. The whole of the exumbrellar and sub-umbrellar surfaces are covered by the epidermis while the cavity of the manubrium and the inner radial canals and circular canal are lined by the gastrodermis. The velum is made up of two layers of epidermis with a core of mesogloea. The epidermis has a large number of stinging capsules. On the radial canals are usually present the gonads, one on each canal.

DEVELOPMENT OF MEDUSA FROM BLASTOSTYLE

The cavity of blastostyle pushes out the coenosarc forming a simple diverticulum. Soon it enlarges to form a small sac with a cavity enclosed by two layers of ectoderm. It is called *bell-rudiment.* It grows in size and assumes the form of sub-umbrellar cavity with the manubrium lying in the centre. Later on the bell-ectoderm (outer ectoderm) breaks up and the remaining part of it constitutes a circular shelf, termed as *velum,* projecting inwards from the margin of the umbrella. It is quite rudimentary here. When the medusa acquires its final shape, mouth breaks through the apex of the manubrium. The stalk also ruptures later on and the medusa becomes free and comes out through the opening at the distal end of gonotheca, and the medusa swims freely in sea-water.

Medusae develop as said above, as buds on the blastostyles. In initial stage of the formation of medusa it is just like a small diverticulum or projection of the cavity of the blastostyle. This diverticulum increases in dimension at its extremity and forms a small vesicle enclosed by ectoderm, mesoglea, and endoderm. It also has enteron of blastostyle. The medusa remains in contact with the balstostyle by a narrow stalk. Subsequently, a cavity appears below the subumbrellar surface by the separation of distal region of ectoderm into two layers: (a) an outer ectoderm and (b) an inner ectoderm. There is a cavity between these two layers of ectoderm.

Radial symmetry. The medusa, like polyp, is also radially symmetrical. The four radial canals mark the four principal radii, called *per-radii* and the tentacles lying against the four radial canals are *per-radial tentacles.* Between any two per radii is the *inter-radius* with *inter-radial tentacles.* Bisecting between a per-radius and adjacent interradius is the *ad-radius* and then the *sub-radius.* Thus there are four per-radii, four inter-radii, eight ad-radii and sixteen sub-radii. In *Obelia,* the radial canals, the angles of the mouth and four of the sixteen tentacles of the young medusa are per-radial, four other tentacles are inter-radial and the remaining eight tentacles bearing the lithocysts are ad-radial.

PHYSIOLOGY

Movement. The *Obelia* colony is fixed and does not show any bodily movement from one place to another. The polyps can control and expand their body and can bend their tentacles.

The medusae, on the other hand, float passively in water and are drifted along the water currents. They also swim actively by muscular contraction. The impulses, originating in the nerves of the umbrella bring about muscular contraction. By rhythmic contraction and expansion of umbrella, the water in the sub-umbrellar cavity is propelled behind and the animal moves ahead

with a series of jerks. The contraction of the bell is brought about by the contraction of the ectodermal muscle-tails which are better developed along the sub-umbrellar surface, specially along the surface where they form a muscle ring. The waves of contraction start from the sub-umbrellar surface and face towards the exumbrellar surface where they are completely absent. The bell opens mainly by the elastic mesogloea and to some extent by the contraction of the muscle-tails in the middle of the upper surface. During swimming, the body of the medusa may be tilted, thrown aside or more often turned inside out so that the sub-umbrellar surface becomes outer and convex with the manubrium arising from its apex.

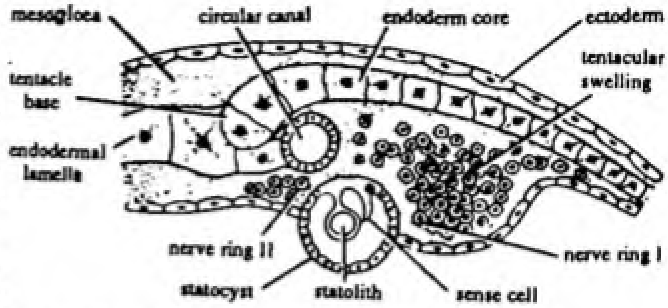


Fig. 25.9 *Obelia*. L.S. of the base of an adradial tentacle of medusa.

Nutrition. The medusa is also carnivorous, feeding on nematodes, insects, crustanceans, small worms etc. The prey is captured by the tentacles with the help of nematocysts and ingested by the highly contractile mouth. The digestion takes place in stomach. It is both extracellular and intracellular. The digested food is distributed to the different parts of the medusa through radial and circular canals.

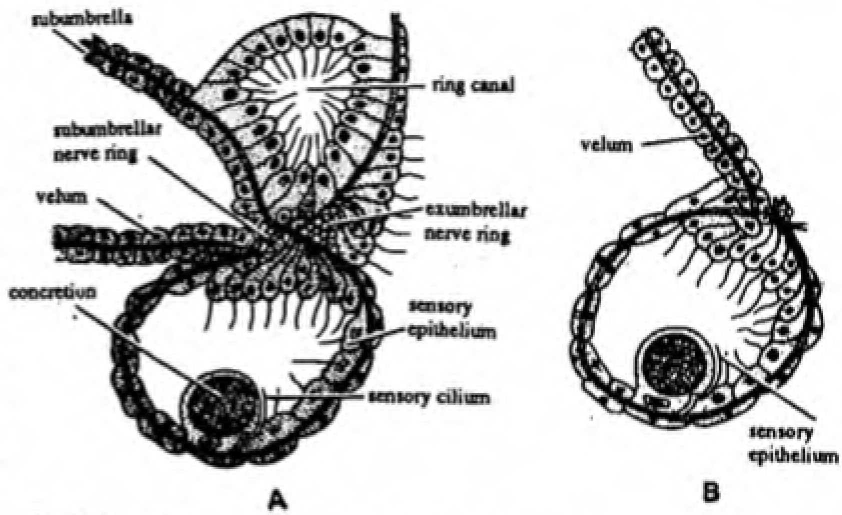


Fig. 25.10 *Statocysts*. A—In horizontal position; B—In tilted position

Nervous system. The nerve cells of the epidermis and gastrodermis are present on either side of mesogloea to form nerve nets. However, the nerve cells are specially concentrated along the margins of the umbrella to form two circular nerve rings on either side just below and above the base of the velum. The upper ex-umbrellar nerve ring supplies the tentacles while the lower nerve ring supplies the sub-umbrellar musculature and statocysts.

Sense organs. The medusa has eight marginal receptor organs situated at the bases of the eight adradial tentacles on the sub-umbrellar surface, just inside the bell-margin. Each consists of a minute and fluid-filled ectodermal sac, called the *statocyst* or *marginal vesicle*. Its cavity contains a movable round particle of calcium carbonate, called *statolith* or *otolith*, secreted by a large cell, termed *lithocyte*. The wall of the statocyst is made of epithelial cells, which are sensory towards the bell-margin, being connected basally with nerve cells. The free inner ends of these sensory cells bear fine protoplasmic sensory processes which arch over the statolith.

The statocysts are considered to be organs of *equilibrium* and muscular *coordination*. Their presence in medusae is associated with their active free-swimming habit. During swimming if the body becomes tilted, the statolith falls over the tilted side against the processes of sensory cells which become stimulated. In this way, nerve impulse is created and transmitted to the nerve ring. As a result, the muscle tails of the stimulated side contract more rapidly and the medusa is brought again into the normal position.

REPRODUCTIVE ORGANS

Each medusa of *Obelia* is unisexual i.e. sperms and ova are produced in separate individuals. The *gonads* are situated on the radial canals in the subumbrellar surface. Actually, each gonad arises as an outgrowth from the wall of the radial canal. It has ectoderm, endoderm and mesoglea as well as an extension of the coelenteron. In fact, the *oogonia* and *spermatogonia* both originate in the ectoderm of the hypostome or manubrium from there they move into the endoderm and later they gradually migrate to the gonads in the radial canals. Before the gonads mature, they reach the endoderm and come to lie between the

ectoderm and mesoglea where their maturation takes place. The sperms and ova come out by rupturing the ectoderm and swim freely in the sea water.

LIFE HISTORY

In *Obelia*, the asexual reproduction takes place by budding as a result of which *hydranths* and *blastostyles* are formed. The blastostyles bud off medusae which are the sexual zooids of *Obelia* because the gonads are found in four groups in each of them. The gonads of a medusa are of the same sex.

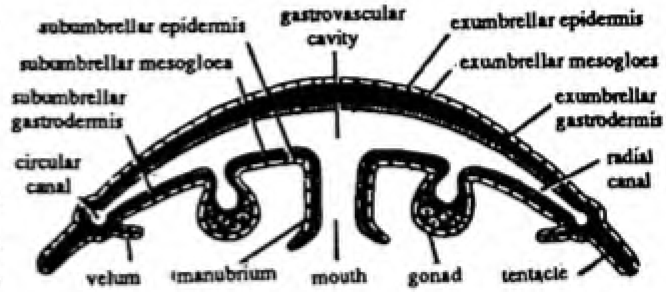


Fig. 25.11 *Obelia*. A vertical section of medusa showing gonads.

Gonads. The gonads are situated perradially on the sub-umbrellar surface. Each gonad is an oval structure which is a group of undifferentiated interstitial cells situated in the mesoglea between the ectoderm and the endoderm. The ectoderm over the gonad is continued with that of the sub-umbrellar surface and the endoderm with the radial canal. The interstitial cells of the gonad form ova in female medusa and sperms in the male medusa. These cells are formed by the ectodermal cells of the manubrium. When the gametes mature, the ectoderm over the gonad ruptures to release them into the sea water.

Fertilization. In *Obelia*, always cross fertilization takes place. The ova are fertilized in the body of the female medusa or in the sea water. The sperms come towards the ova along with the water current.

Development. The zygote undergoes holoblastic and repeated equal clevages forming a *blastula* which is hollow. The cavity of blastula is called *blastocoel* which is surrounded by a single layer of cells. Soon the cells start separating from the wall of the blastostyle and collect in the blastocoel due to which it becomes completely filled up by them. Thus, a solid gastrula or stereogastrula is formed as a result of delamination and multipolar immigration of the ectodermal cells. The outer layer of cells of the gastrula forms the ectoderm of the adult while the inner layer of cells forms its endoderm. After some time, cilia appear in the cells of ectoderm. Simulataneously, a *colenteron* in the centre is formed by the delamination of the endodermal cells. The gastrula in this stage is known as *planula larva*. It comes out by the rupture of the brood pouch and swims freely in the sea water.

Metamorphosis. After leading a free swimming life for some time, the planula larva settles down and attaches itself by its broad anterior end to some object and the process of metamorphosis starts in it. Its anterior end forms the basal disc by which the animal remains attached to the substratum and the posterior end forms the manubrium. A mouth is formed at the free end of the manubrium around which a circlet of tentacles is present. In this way a simple polyp-like structure is formed which is called *hydrula stage*. The basal part of hydrula elongates to form the *hydrorhiza* from which vertical and lateral branches arise forming the adult *Obelia* colony. Again the medusa buds arise on the balstostyles of this colony and start the sexual generation.

The free swimming medusae are very important in a fixed animal like *Obelia* because they help in its far and wide distribution so that more facilities may be available to it.

Alternation of Generations or Metagenesis

The life-cycle of *Obelia* colony described above gives the impression that alternation of

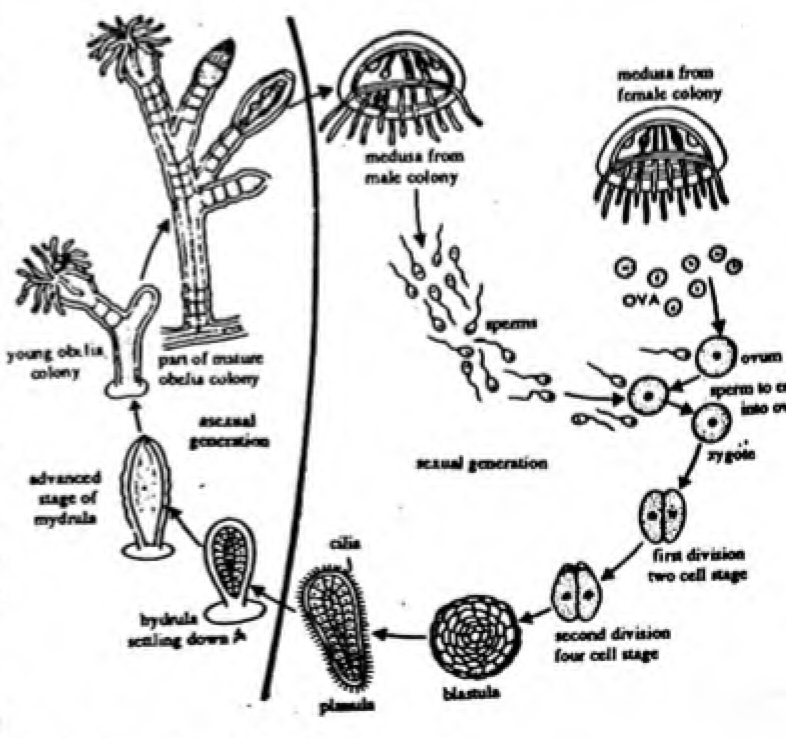


Fig. 25.12 Life-cycle of *Obelia*

generations or metagenesis takes place. The sedentary colonial asexual hydroid phase gives rise by budding to medusae which represent the sexual generation. The gonads of medusa produce sperms and ova. The fertilized ovum ultimately gives rise to planula larva which gives rise to *Obelia* colony. In other words the sexual medusa gives rise to asexual colony by sexual method. This alternation of generations or metagenesis confers upon the species not only genetical advantage but also ecological advantage. When each asexual and sexual form has a large reproductive capacity, one sexual, the other asexual, the species has the less chance of being eliminated due to predation or competition. However, in the strict sense the life-cycle of *Obelia* does not represent a true case of alternation of generations which occurs in the life-cycle of certain plants such as Ferns, the asexual diploid (2n) phase forms haploid (n) sexual phase by its single cell. But in the case of *Obelia*, both the sedentary asexual colonial polypoid generation and mobile sexual medusoid generation are diploid (only the sperm and ova produced in the gonad of medusa having brief existence are haploid). Moreover, the medusa (sexual phase) is not derived from a single cell of the asexual phase but is formed by many cells of the blastostyle by budding. Hence the life-cycle of *Obelia* though apparently seems to represent alternation of generations does not do so in *strict sense*.

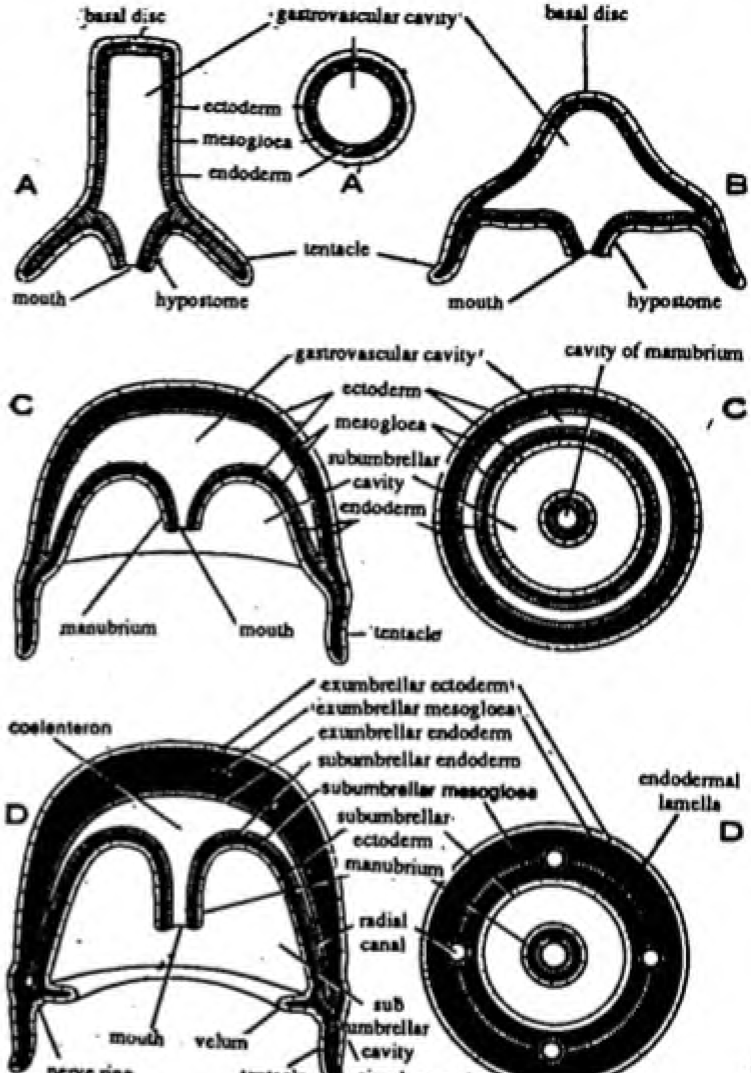


Fig. 25.13 Diagram illustrating the derivation of the *medusa* from the polyp. A—Polyp in L.S., A'—Polyp in T.S., B—Polyp from with extended tentacular region, C—Vertical and C' transverse section of form with tentacular region extended into the form of a bell; D—Vertical and D' transverse section of medusa.

COMPARISON OF POLYP AND MEDUSA

The polyp and medusa of *Obelia* are two different kinds of zooids which differ from each other in the structure, shape and other respects. These differences are according to their varying functions. The polyps are nutritive and the medusae are reproductive in function. Thus they are different in shape according to their functions. Their basic structure is, however, the same because of which some similarities are also found in them. Therefore, the comparison between polyp and medusa can be done only on the basis of similarities and dissimilarities in them.

(a) **Resemblances.** Apparently there seems to be no similarity between the polyp and the medusa. Actually, however, the two are homologous structures, being built on the same fundamental plan. Resemblance between the two is so close that one can be easily derived from the other. An inverted polyp at once assumes the medusoid form if its region of tentacles is pulled out and manubrium is pushed up. This, together with the thickening of mesogloea, especially on the upper side, brings the walls of the polyp together so that they meet everywhere to form the *gastrodermal lamella* except along the radial and circular canals. Thus, we find that the manubrium, subumbrellar surface, exumbrellar surface and tentacles of the medusa correspond to the manubrium, oral side, aboral side or foot, and tentacles of the polyp respectively. Moreover, the polyp and the medusa have the same layers, which occupy the same relative positions in both, the epidermis covering the outer surface, the gastrodermis lining the cavities and the mesogloea lying between the two. In both, the gastrovascular cavity has a single outlet and both have solid tentacles bearing cnidoblasts. The nature of food and modes of capturing and digesting it are also similar in the two. Finally, both arise as buds on the colony and show radial symmetry.

DIFFERENCES BETWEEN POLYP AND MEDUSA

Polyp	*Medusa*
1. Body of the polyp is long and cylindrical.	1. Body of the medusa is short and bell shaped or umbrella-like.
2. Polyp is a fixed zooid.	2. Medusa is a free-living zooid in the mature stage.
3. Polyp is enclosed in a transparent protective covering, the hydrotheca.	3. Medusa is without any covering.
4. The mouth of the polyp is circular and lies at the upper end of the upright manubrium.	4. The mouth of the medusa is foursided and lies at the lower end of the hanging manubrium.
5. The tentacles of the polyp are situated at the base of the manubrium.	5. The tentacles of the medusa are situated at the margin of the umbrella.
6. There is no velum.	6. Velum, which is a small inward projection all along the margin, is present.
7. The gastrovascular cavity is a single spaceous cavity occupying the whole of the body of the polyp.	7. The gastrovascular cavity is restricted and differentiated into the cavity of the manubrium, radial canals and a circular canal.
8. There are no endoderm lamellae.	8. There is an endoderm lamella between radail canals in each quadrant.
9. The mesogloea is almost of uniform thickness throught.	9. The mesogloea is much thicker on the exumbrella side than on the other side.
10. The nervous system is poorly developed, consisting only of a double nerve-net.	10. The nervous system is much better developed, consisting of a double nerve-ring and a double nerve-net.
11. There are no sense organs.	11. There are eight sense organs, the statocysts.
12. The polyp feeds and protects the colony.	12. The medusa brings about sexual reproduction and dispersal of the colony.
13. Polyps are produced directly on the hydrocauli.	13. Medusae are produced on the blastostyles and not directly on hydrocauli.
14. Polyp belongs to the asexual generation.	14. Medusa belongs to the sexual generation.

Medusa shows a distinct morphological advancement over the polyp in having sense organs and nerve-ring in the nervous system; almost an independent muscular tissue; differentiation of gastrovascular cavity into region like gullet, stomach, radial canals and circular canals; gonads for sexual reproduction; and free-swimming life.

Polyp Versus Hydra

Polyp of *Obelia* resembles *Hydra* in form, structure and mode of feeding. The two, however, differ in many respects. The more obvious differences are tabulated below --

Comparision of the Structure of *Hydra* and *Obelia*

Hydra	*Obelia*
1. *Hydra* is a solitary animal but because of the presence of buds, sometimes it may also be branched. Later these buds separate from the parent and lead independent life.	1. *Obelia* is a colonial animal. It appears like a branched tree because - the lateral branches do not separate from it.
2. It is semi-sedentary and remains temporarily attached on aquatic plants, stones or the wall of the pond. It can be occasionaly seen floating in water. The *basal disc* helps in attaching it to the substratum.	2. It is fully sedentary and ramins permanently attached to marine plants and rocks. It is attached to the substraum by means of *hydrorhiza.*
3. Polymorphism is absent in it. Only polyp or hydranth stage is found. (a) Polyp or hydranth (b) Blastostyle (c) Medusa.	3. It is a polymorphic animal which is found in three forms.
4. There is no covering around it	4. The polyp is enclosed in a conical cup-shaped *hydrotheca.*
5. Its body is long and cylindrical, and its lower end closes to form the basal disc by which it remains attached to the substraum.	5. The polyp is long and wine glass-shaped. Its both the ends are open and lower end is connected with the hydrocaulus through a circular shelf.
6. The free distal end of *Hydra* is conical and called *hypostome.* There is a mouth at its apex.	6. The hypostome of polyp forms its 1/3 part and a mouth is present at its apex.
7. There are 6 to 10 tentacles around the mouth on the hypostome. These tentacles are hollow.	7. The number of tentacles around mouth is about 25 and they are solid.
8. A thin transparent membranous cutile forms the outer covering of the body of *Hydra.* The perisarc is absent.	8. The cuticle is absent in *Obelia* and the whole colony is covered by a thick and tough *perisarc.*
9. The body wall of *Hydra* is made up of two layers the outer *ectoderm* and the inner *endoderm.*	9. The same two layers are found in *Obelia.*
10. A non-cellular *mesoglea* is present between these two layers.	10. The mesoglea is also non-cellular.
11. It is not so in *Hydra.*	11. The two layers of the polyp are united with the two similar layers of the hydrocaulus.

Hydra	*Obelia*
12. A gastrovascular cavity is present but it is closed at the lower or basal end.	12. The gastrovascular cavity of the polyp is in communication behind with the coenosarc of the hydrocaulus and the hydrorhiza.
13. The following seven types of cells are found in the outer layer (ectoderm). (a) Epithelial cells (b) Interstitial cells (c) Nematocysts (d) Sensory cells (e) Nerve cells (f) Gland cells (g) Reproductive cells.	13. Only five types of cells are found in the outer layer (ectoderm) of the polyp. The gland cells and reproductive cells are absent in it.
14. The nutritive and reproductive activities both are done by the *Hydra*. The blastostyles and medusae are absent in it.	14. In *Obelia*, the polyp is only nutritive form which supplies food to the colony. It has no reproductive function. The blastostyles (asexual) and medusae (sexual) are the reproductive forms.

Hydra and *Obelia* both are the members of the Order Hydroidea, Class Hydrozoa and Phylum Coelenterata, by which it is apparent that there should be many similarites between them, however, there are also many dissimilarities in them. The following differences are met within their life histories.

Differences between the reproduction and life histories of *Hydra* and *Obelia*

Hydra	*Obelia*
(A) Reproduction	
1. The reproduction in *Hydra* takes place by two methods: (a) Asexual (b) Sexual	1. Only sexual reproduction occurs in *Obelia* although the whole colony grows by asexual method of budding.
2. The asexual reproduction mostly occurs by *budding*. *Hydra* is also capable of fission and regeneration. The bud separates from the parent body after sometimes and leads an independent life	2. In asexual reproduction, the colony increases in size and new *zooids* are formed which do not separate from parent colony.
3. The sexual reproduction takes place by the formation of gametes.	3. The gametes are also formed in *Obelia*.
4. The gonads are formed in the polyp condition in *Hydra*. Therefore, the polyp also acts as a reproductive zooids.	4. The gonads are formed in the medusa form in *Obelia*.

Hydra	*Obelia*
5. *Hydra* is mostly bisexual but unisexual individuals also occur.	5. The medusa of *Obelia* is always unisexual.
6. The gonads of *Hydra* are temporary structures which are formed only during breeding season.	6. The gonads of *Obelia* are permanent structures.
7. The gonads are formed from the interstitial cells of the ectoderm and project out on the body wall. There is only a layer of ectoderm on their outer side.	7. The gonads are formed on the subumbrellar surface from the ectoderm and are situated in the mesogloea between the ecto-and endoderm.
8. The number of gonads is not definite.	8. Only four gonads are present in a medusa.
9. The male gonads or testes are found in the anterior region of the body while the female gonads or ovaries are situated in the posterior region near the base.	9. The gonads in medusa are of one sex only i.e. either male or female and are radial.
10. The reproductive cells are formed by the division of interstititial cells and collect together to form gonads.	10. The reproductive cells are formed in the ectoderm of the manubrium and migrate to mesogloea to form gonads.
11. The matured female gametes do not come out in water from the parent body.	11. The male and female gametes both separate from the parent body after maturation and swim freely in water.
B. Life History	
12. The fertilization is external and completed in the ovum while attached to the parent body.	12. The fertilization is external and takes place in the ovum swimming in the water.
13. The development of the zygote takes place in the parent body.	13. The development of zygote takes place in water.
14. The clevage of the zygote is holoblastic and equal.	14. The clevage of the zygote is also holoblastic and equal.
15. A solid ball-like morula is formed as a result of division. Later with the formation of blastocoel, a blastula having eight blastomeres is formed.	15. A solid morula is formed by division. It later changes into a single layered hollow blastula.
16. As a result of delamination the blastula changes into a two-layered gastrula.	16. By the process of delamination, the blastula changes into a solid gastrula.
17. A double layered cyst is secreted by the outer layer of the gastrula around the embryo. The outer cyst wall is thick, hard and spiny but the inner cyst wall is thin and geletinous.	17. Cilia are formed on the ectodermal cells of the gastrula as a result of which an oval, ciliated *planula* larva is formed.

Hydra	*Obelia*
18. In the encysted condition, the embryo detaches from the parent body and lies in the mud of the pond and remains in dormant condition.	18. The planula larva leads a free swimming life and does not rest.
19. The cyst ruptures with the onset of favourable conditions in spring season and a small *Hydra* comes out of it which grows into the adult.	19. After leading a free swimming life, the planula larva attaches to some substratum and transforms by growing into an adult colony. The planula first changes into *hydrula* which forms the different zooids of the colony by budding.
20. Alternation of generations is not found in the life history of *Hydra* because only one form of zooids is found in it.	20. Alternation of generations or metagenesis occurs in the life history of *Obelia*. A regular alternation of asexual and sexual stages is found in it.

26

AURELIA

Aurelia is a common jelly fish. Animals known as 'Jelly Fishes' are kept in Scyphozoa. Probably the name is derived due to the presence of jelly-like substance forming most of their body. The word fish attached to these animals is unsuitable because they have no connection with fishes except that both are found in water.

SYSTEMATIC POSITION

Phylum	-	Coelenterata
Class	-	Scyphozoa
Order	-	Samaeostomae
Genus	-	*Aurelia*

HABITS AND HABITAT

Aurelia is almost cosmopolitan in distribution. It is found in tropical and temperate seas. It inhibits the costal waters, generally remaining at or near the surface. It is generally seen floating separately or in groups, by rhythmic contractions of the bell. It is often found cast upon the seashore and is recognized by its gelatinous saucer-shaped umbrella, 3-4 inches in diameter and by four red or purple horse-shoe shaped gonads in its centre.

MORPHOLOGY

Shape and Size. *Aurelia* has a flattened, saucer-shaped body often referred to as the *umbrella* or *bell.* It generally measures upto four inches. The dorsal (exumbrellar) surface of the bell is convex and the ventral (subumbrellar) surface is concave. The umbrella is transparent.

Colouration. The umbrella is bluish-white in colour through which red or pink gonads are visible.

Symmetry. It possesses *tetramerous radial* symmetry *i.e.* the body parts are symmetrically arranged around the oral-aboral axis in four or some multiple of four.

External Characters. The body is very much like that of hydromedusa having the form of an umbrella, a convex *exumbrellar* side and a concave *subumbrellar* side.

In the centre of the subumbrellar side is a short and inconspicuous *manubrium.* The manubrium have a square mouth at its free end. From each corner of mouth hangs down a long, tapering much frilled and delicate process, the *oral arm.* Each arm has a ventral ciliated groove leading into the mouth. The edges of the arms have a large number of

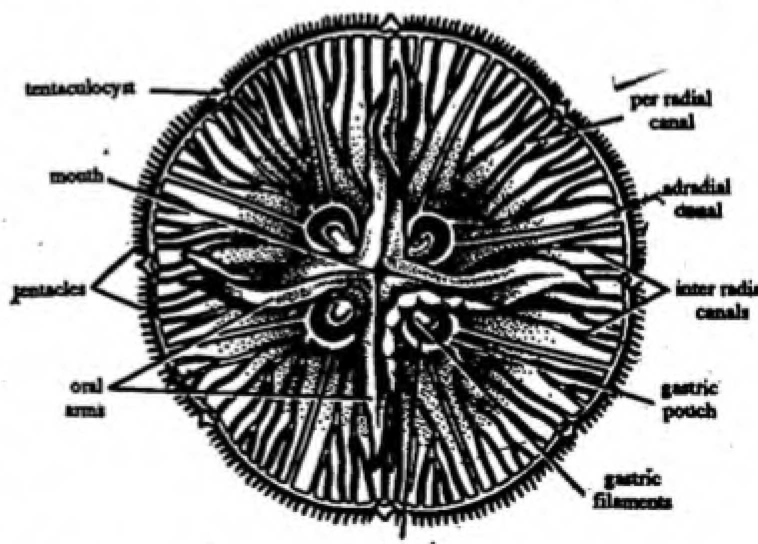


Fig. 26.1 *Aurelia aurita.*

nematocysts. The angles of mouth and the oral arms lie along per-radii. Midway between two adjacent per-radii is an inter-radius. Between each par-radius and its adjacent inter-radius is an ad-radius on either side.

Four round apertures are present between the oral arms, a little away from the mouth, on subumbrellar surface. These apertures open into *subgenital pits*. Each pit is in the form of hollow and shallow depression and lies beneath gonad. Their function is uncertain. Four pink or red horse-shoe shaped gonads present just above the subgenital pits. They are visible through the transparent umbrella.

The margin is indented with eight equally-spaced notches of which four are per-radial and four inter-radial. A sensory organ called *tentaculocyst* or rhopalium is situated in each notch. Two delicate protective *marginal lappets* are found over each tentaculocyst. Between the notches, the edge of umbrella is fringed by a row of numerous, short, hollow *marginal tentacles*, set closely together.

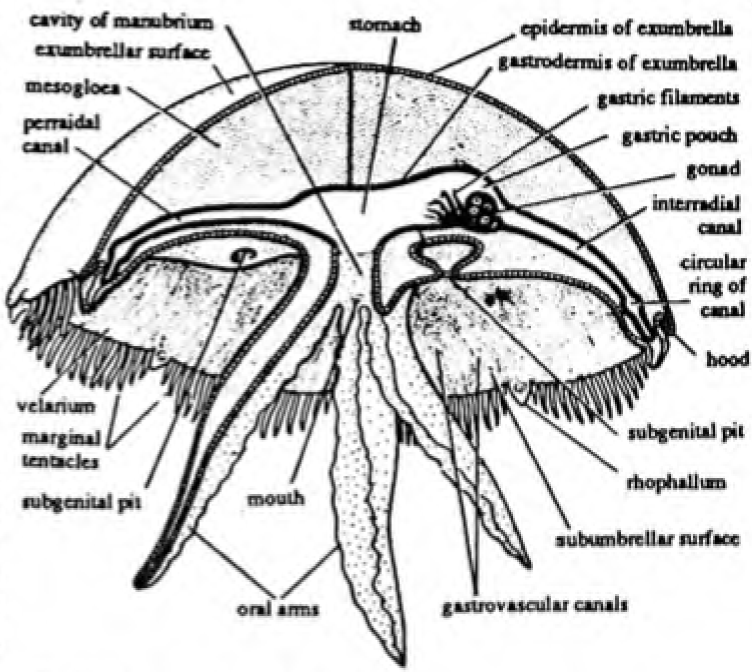


Fig. 26.2 *Aurelia aurita*. Lateral view.

The tentaculocysts, marginal lappets and tentacles all are attached to an extremely flexible fold called *velarium* on the umbrella. A true velum, like that of *Obelia*, is absent. It differs from true velum in having gastrodermal canal running into it.

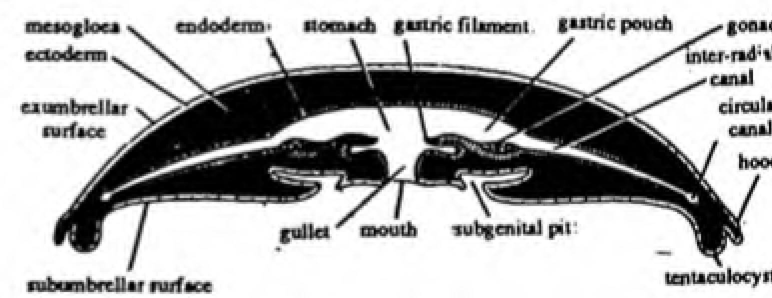


Fig. 26.3 *Aurelia aurita*. V.S. (diagrammatic).

Histology. The main types of tissues and their arrangement in *Aurelia* are practically similar to those found in other hydrozoan medusa (*Obelia*).

1. *Epidermis.* The exposed part of umbrella *i.e.* exumbrellar as well as subumbrellar surfaces, velarium, manubrium, oral arms, marginal tentacles etc. are covered with epidermis. The epidermis also lines subgenital pits. It consists of epithelial cells on the exumbrellar surface while the subumbrellar surface contains epithelio-muscular cells besides sensory cells, nerve cells, gland cells and cnidoblasts. It forms sensory epithelium for the sense organs. The muscle processes of the epidermal cells are cross-striated at certain places and smooth at others.

   The cnidoblasts occur on the oral arms, ex-and sub-umbrellar surfaces, marginal tentacles and gastric filaments. There are two types of such cnidoblasts:

   (a) *Atrichous isorhizas.* The capsule is oral or elongate and the thread is open at the tip. The butt and spines are absent.

   (b) *Heterotrichous microbasic euryteles.* The capsule is small and the thread is open. The thread remains covered by minute spines. The butt is small and its distal dilated portion bears unequal spines.

2. *Gastrodermis.* All the parts of digestive cavity *viz.* gullet, stomach, gastric pouches, radial canals and circular canals all are lined by gastrodermal cells. It consists of columnar epithelial cells which are flatenned throughout to maintain a current of water. Gland cells are also present but nerve cells and muscle processes are absent. The gastric filaments possess the cnidoblasts but they are absent from the gastrodermis.

3. *Mesogloea.* Between the epidermis and endodermis is a very thick layer of jelly-like mesogloea. It forms the main bulk of

the bell. It is not structureless like the mesogloea of *Hydra* or *Obelia* as, it contains elastic fibres and free wandering amoeboid cells. These cells are derived from ectomesodermal cells. Such a mesogloea is more or less like connective tissue and is more accurately termed *collenchyme.*

Muscular System. Musculature in *Aurelia* is practically wholly epidermal and confined to the subumbrellar surface. It is formed by the muscle processes of epidermal epithelial-muscle cells. The muscle processes form strong longitudinal muscles in the tentacles, manubrium and axes of the oral arms. The subumbrellar muscles are striated and arranged in a strong broad and circular peripheral band called the *coronal muscle.* It is composed of regular muscle fibres, each consisting of a complete epidermal cell. The coronal muscle forms the swimming organelle of *Aurelia.* The muscle fibres of coronal muscle and muscle-processes of longitudinal tentacle muscles are cross-striated and capable of rapid contraction. Another muscles, the *radial muscles* extend along the main radii from the manubrium to the coronal muscle.

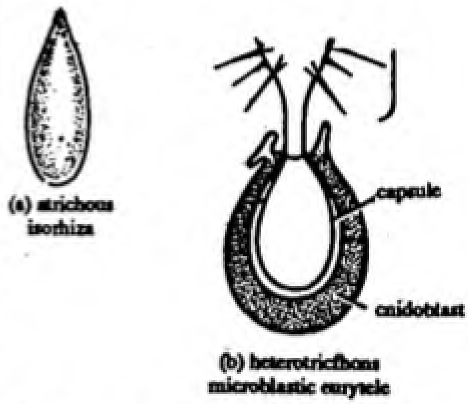


Fig. 26.4 *Aurelia.* Types of nematocysts.

PHYSIOLOGY

Locomotion. *Aurelia* swims by powerful rhythmic contractions of its body muscles, during which the exumbrellar surface is kept upwards.

The contractions force the water back from the subumbrellar cavity and this pushes the bell forwards. This is an elementary form of jet-propulsion, called *hydropropulsion.* The contractions are brought about by the highly developed coronal muscle and radial muscles. The tentaculocysts serve as the organ of equilibrium during swimming. Removal of all the eight tentaculocysts stops pulsations. When the contractions stop, the body gradually sinks to the bottom. Horizontal movements are brought about by wave-action and currents.

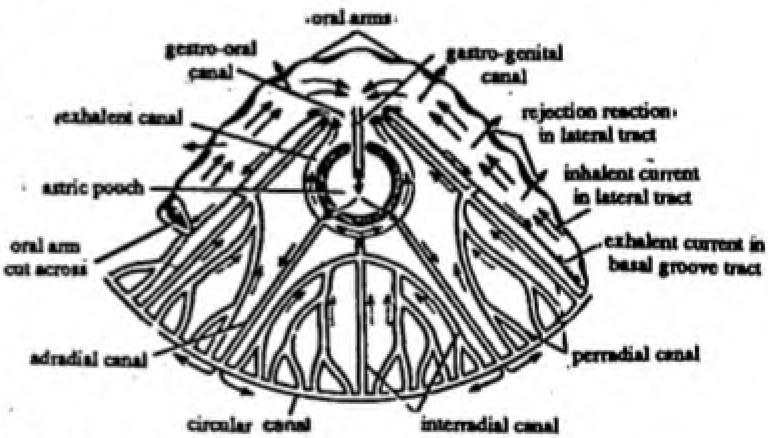


Fig. 26.5 *Aurelia.* Diagramatic representation of gastrovascular system.

Gastrovascular System. The mouth which is situated at the tip of the manubrium leads into a short *gullet* which opens into a large rectangular *stomach.* The stomach is produced laterally into four gastric pouches which are inter-radial in position. At the four corners of the mouth are branched four *per-radial canals* at right angles to each other, and between them are four *inter-radial canals* which are very much branched and end at the *marginal lappets.* Halfway between the per-radial and inter-radial canals are eight unbranched *ad-radial canals,* two of them arising from each gastric pouch. From the inner concave border of each gastric pouch, a number of small thin gastric filaments are given out which form a regular row. Each consists of a fold of endoderm and a central core of mesogloea and bears a large number of nematocysts.

The ad-radial canals open into a *circular canal* running to the margin of the bell. Thus there are 16 canals in total, all of them open into a marginal circular canal. The gullet, stomach with its gastric pouches and all the canals constitute an enteron cavity or gastro-vascular system which is lined with *ciliated endodermal cells.* The beating of the cilia causes the circulation of the fluid. The water drawn into the mouth goes to gullet then into stomach and gastric pouches and then through the ad-radial canals to the circular canal from where it returns by the branches per-radial and inter-radial canals to the exhalent groove of oral arms and from here it goes out. Thus enteron is a gastrovascular cavity.

Food. *Aurelia* is exclusively carnivorous. The food consists of small marine invertebrates such as worms, crustaceans and small pieces of animals.

Ingestion. By the beating of cilia of the endodermal cells circulates a water current through the gastrovascular cavity or canal system in a definite direction. Water along with the food, is caught into the folds of the oral arms from where it is passes into the gullet through the mouth. From there it moves into the stomach and then into the gastric pouches. Here the alive prey is paralysed and killed by the nematocysts of gastric filaments. *Intercellular digestion* is started here by the enzymes containing the juice from the gland cells. From the pouches digested and undigested food, with water current reaches the radial and circular canals where *intracellular digestion* occurs in the gastrodermal cells. The undigested food is returned back to the stomach and escape with the outgoing water.

Digestion. *Aurelia* secretes most of the digestive enzymes. The enzymes digest proteins, carbohydrates, fats and even chitin. The digested food is collected and distributed by the wandering amoebocytes of the mesogloea. Reserve food is in the form of fat droplets and glycogen. These are stored by the gastrodermal cells and of the gastric filaments.

It is thus clear that the entire gastro-vascular cavity performs functions of digestion as well as circulation of higher animals. The entire circulation from the gullet back into it takes about 20 minutes and helps in a proper distribution of the food substances to the different parts of the body. Besides bringing food, the water circulation also brings oxygen for respiration and carries away waste products, sex elements etc. along with undigested food.

Water circulation. The circulation of water is brought about by the beating of cilia of the lining gastrodermis in definite directions. Water entering mouth passes into stomach, thence to the gastric pouches. From the exhalent channels of the gastric pouch it goes into the ad-radial canals, then into the circular canal. Water returns from circular canal in the branches of inter-radial and per-radial canals. Inter-radial canals bring the water into the gastric pouches, it flows through the inhalent channel and back to the gullet. Per-radial canals return the water directly into the gullet just near the base of grooves of the oral arms, which are exhalent. Thus, water returns both ways is eventually passed on the oral grooves. It may be seen that in such a course the incoming water-current is not polluted by the outgoing current.

Respiration. There are no specialized organs for respiration thus entire body surface presumably perform the respiratory function. Respiration is aerobic. The epidermal cells are in contact with surrounding water and the gastrodermal cells are in contact with surrounding water and the gastrodermal cells are bathed by water current circulating in canal system. Water containing oxygen is diffused into the cells and carbon dioxide is diffused out in the water.

According to some workers, below each gonad on the subumbrellar side is situated a sub-genital pit, in which by rhythmic contractions of umbrella, water enters and constant change of water may be responsible for the process of respiration through general body surface.

Excretion. Nitrogenous waste products are eliminated out by the processes of diffusion from epidermal and gastrodermal surfaces. In the deeper parts of mesogloea these are eliminated by the wantering cells, which ingest them.

NERVOUS SYSTEM

The nervous system is epidermal, simple but formed on a different plan from that of hydroid medusa (*Obelia*). The following structures are found in the nervous system.

(i) Subumbrellar plexus or Main nerve net.

(ii) Rhopalial ganglia.

(i) *Subumbrellar Plexus.* It is formed of very long bipolar nerve cells and nerve fibres and extends between the ectoderm and upper muscular layer on the subumbrellar surface. It consists of two different and definite plexuses.

The subepidermal plexus into the manubrium, oral lobes and tentacles white the sub-gastroder-

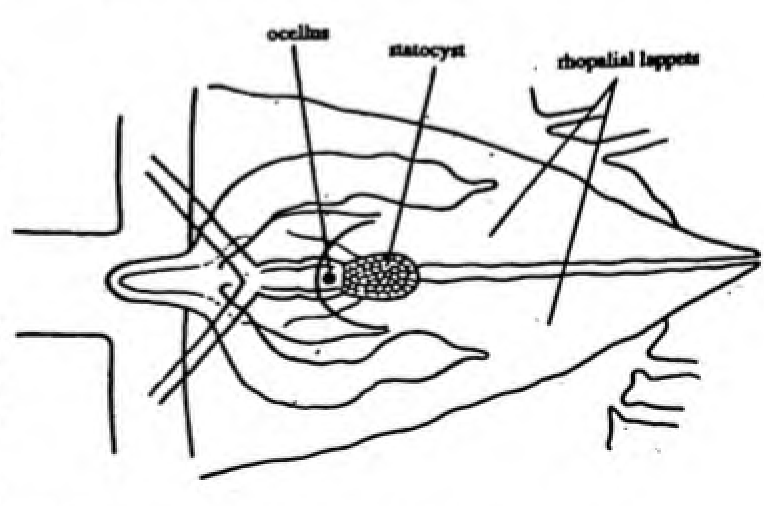


Fig. 26.6 *Aurelia* Rhopalium (diagrammatic).

mal plexus lies in the wall of gastrovascular system. The nervous system is much thicker in the radial position. It is much thickened and distinct at the places of pe-rradii and inter-radii, and situated near the marginal notches and sensory organs. These plexuses control the contractions of the bell.

Besides another diffused nerve plexus occurs in both the subumbrellar and exumbrellar epidermis. It controls the local activities, like feeding and can prevent the contractions of the bell.

(ii) *Rhopalial Ganglia.* These are aggregation of nerve-cells, one near each sense organ or rhopalium. They are connected with the nerve-nets but, not directly with each other.

There is a ring of nerve cells along the margin of umbrella. It runs along the marginal or circular canals.

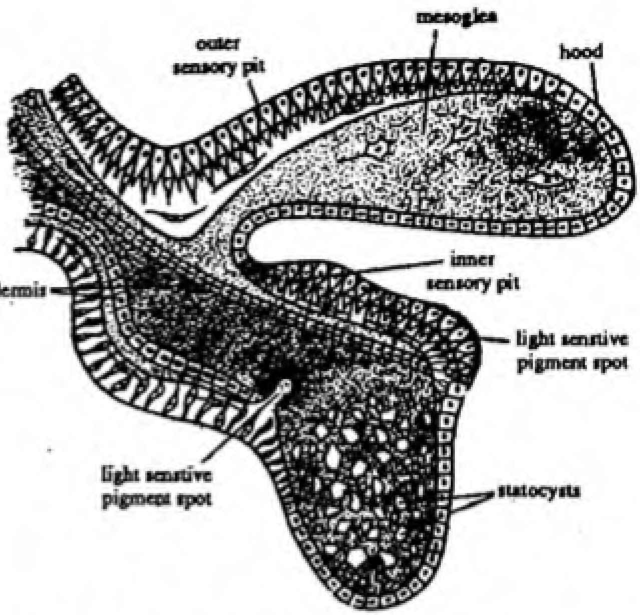


Fig. 26.7 Section through showing *hood* and *sensory organs*.

Sense Organs. There are three kinds of sensory organs in *Aurelia*:

1. The sensory tentacles or tentaculocysts.

2. Ocelli.

3. Sensory pits.

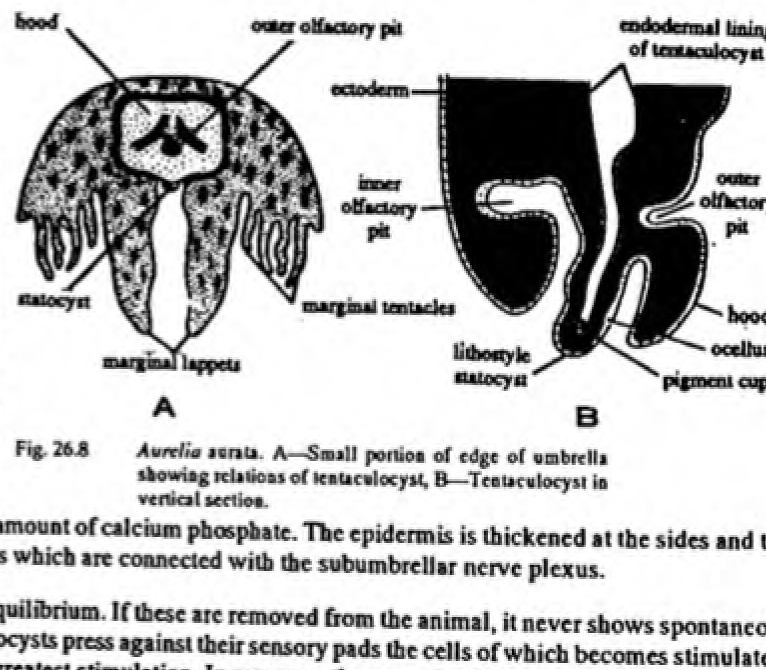


Fig. 26.8 *Aurelia aurata*. A—Small portion of edge of umbrella showing relations of tentaculocyst, B—Tentaculocyst in vertical section.

1. *Tentaculocysts.* There are eight club-shaped tentaculocysts lying between marginal lappets at the end of inter-radial and per-radial canals. Each tentaculocyst is covered on the outer side by a process of the bell-margin known as hood. A pad of ciliated sensory epithelial cells is present below the club of tantaculocyst. The circular canal projects into it and thus it is a hollow tentacle lined by gastrodermis. The gastrodermal cells heap up in the distal part of the tentaculocyst as a mass of polylgonal cells. Each cell of this mass secretes a calcareous particle called *statolith.* The statolith composed of calcium sulphate mixed with a small amount of calcium phosphate. The epidermis is thickened at the sides and the base of tentaculocyst and contains tall sensory cells which are connected with the subumbrellar nerve plexus.

The tentaculocysts are regarded as organs of equilibrium. If these are removed from the animal, it never shows spontaneous movements. If the bell is tilted the clubs of tentaculocysts press against their sensory pads the cells of which becomes stimulated. On tilting the highest, tentaculocyst produces the greatest stimulation. In response the upper half of the bell derives less water than the lower half, at each beat, with the result that the bell automatically rights itself.

2. *Ocelli.* There are two ocelli, one of them is ectodermal in origin while other is endodermal. The ectodermal ocelli is known as *pigment spot ocellus.* It is formed of a patch of pigmented and sensory epidermal cells lying on the outer side of the tentaculocyst. The other ocellus is called as *pigment cup ocellus* as it is a cup-shaped cavity lined by pigmented and sensory endodermal cells, lying on the inner side of the tentaculocyst in association with the statoliths. The sensory cells of both the ocelli are connected with the respective nerve plexus. Both the ocelli are photoreceptor being sensitive to light.

3. *Olfactory pits.* These are two depressions, one internal to the statocyst and other above the hood. These are called *adoral* and *aboral* olfactory pits respectively. These are lined with sensory epithelium and receives chemical stimuli.

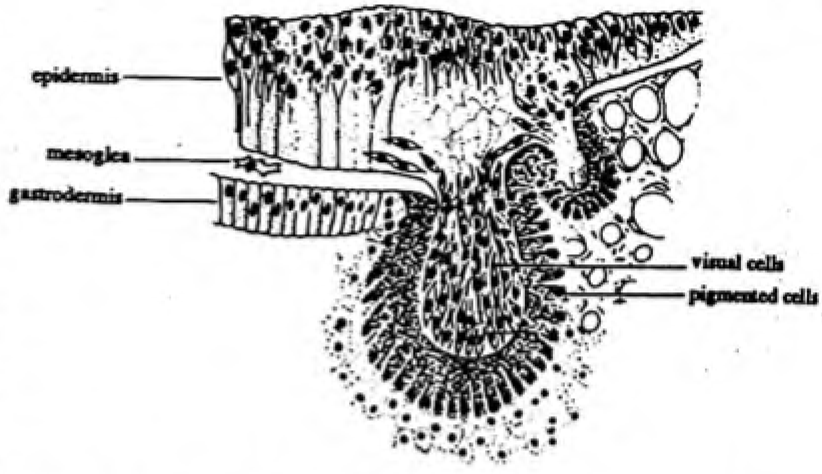


Fig. 26.9 *Aurelia* aurita. Section double ocelli.

REPRODUCTIVE SYSTEM

Aurelia is *dioecious* or unisexual but they are alike in structure *i.e.* there is no sexual dimorphism. Four gonads (testes or ovaries) lie interradially on the floor of the gastric pouches. The gonads are horse-shoe shaped. Their colour is reddish or pinkish. The gonads are endodermal in their origin. The testes of mature male liberate spermatozoa into the genital pouches from where they pass out through the mouth with the out going water. The female gametes or ova are liberated in the genital pouches where they remain till fertilization occur.

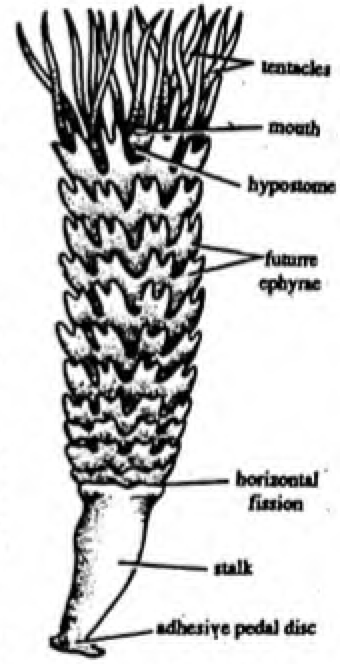


Fig. 26.10 *Aurelia*. A strobila.

Fertilization. Fertilization is effected in the gastro-vascular cavity of female medusa. The spermatozoa from water find their way into the female with the ingoing water current and reach its genital pouch. Here, fertilization takes place. Thus fertilization is *internal*. The zygote or fertilized eggs pass out with the outgoing water current and get lodged in the grooves of the oral arms of the female. Thus oral arms serving as temporary brood chambers and development takes place within these chambers.

Cleavage. The zygote undergoes holoblastic but unequal cleavage to produce a solid, ball-like *morula*. The morula changes into a single-layered hollow, closed sphere, the *blastula* by developing a fluid filled central cavity or blastocoel. The blastula undergoes gastrulation by an invagination. Thus a two layered *gastrula* is formed which has an outer layer of ectoderm and inner layer of endoderm enclosing a cavity, the *coelenteron cavity* which has an opening, the *blastopore*. As the invagination progresses, the coelenteron cavity enlarges at the cost of blastocoel which finally disappeasr. The gastrula elongates and its ectoderm develops cilia the blastopore is closed. Thus the embryo becomes a free swimming oval *planula larva*. The planula differs from the planula of Hydrozoa in its method of formation and in having a coelenteron and blastopore. These larvae, can be seen on the oral arms of female *Aurelia*.

Planula larva. They become free from the oral arms of the female and after a short free swimming they sink at the bottom of sea. Now planula loses its cilia and the larva is fixed to the substratum by its broad aboral end.

The planula metamorphoses into a small trumpet-shaped polyp or *hydratuba* which has a manubrium and the blastopore opens to become the mouth. Later, the tentacles are also formed around the mouth first of all, two *per-radial* tentacles as buds. After sometimes two other per-radial tentacles are formed longitudinally to the first two are formed and then four *inter-radial* and eight *ad-radial* tentacles arise. The endoderm of coelenteron forms four inter-radial longitudinal ridges called the *gastric ridges* or *mesenteries*. The mouth becomes square and the manubrium forms funnel-like depression called *septal funnel* or *infundibula*. These changes convert the planula into a hydratuba. A stolon arises at the base of hydratuba.

The hydratuba buds off new hydratubae, from its stolon in summer. These hydratubae may separate after summer. Hydratuba stops budding but each continues to feed and generally passes the winter of the first year and buds other hydratubae. In the next winter the hydratuba undergoes a process of transverse fission, *strobilation*. The dividing hydratuba is called *Scyphistoma* or *Strobila*.

Strobilation of Scyphistoma. In winter and autumn seasons, the body of scyphistoma divides by a series of ring-like transverse constrictions. These constrictions gradually deepen and the body of scyphistoma appears like many saucers placed upside down over each other. The segmented scyphistoma is known as the *strobila* and the process is strobilation and its saucer-like segments as the *ephyrae* or *ephyrulae*.

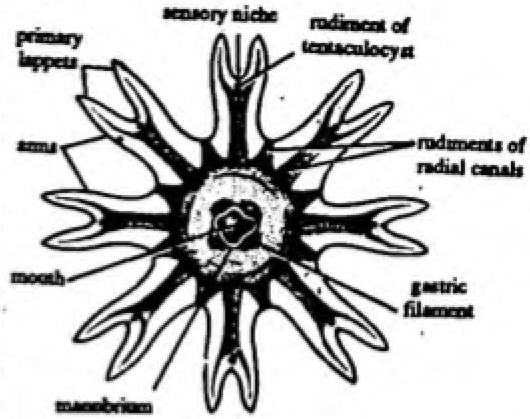


Fig. 26.11 *Aurelia*. A free ephyra.

During the formation of the ephyrae, eight bifid arms, 4 per-radial and 4 inter-radial grow out from the periphery. A rhopalium appears in the terminal notch of each arm. The gastric ridges break down, septal funnals disappear due to expansion of the area occupied by them. The enteron sends a branch in each arm. When fully formed, the ephyrae break from scyphistoma. The scyphistoma loses its tentacles before it casts off the first ephyra. Thus the ephyrae are constricted off one by one from the upper surface of scyphistoma. The successive ephyrae released from strobila have no tentacles. While the ephyrae are being detached, their enteron closes on the proximal side but on the distal side it remains open and its margin grows out to form a short manubrium with a square mouth at its tip. This side becomes subumbrella while proximal becomes exumbrella.

Strobilation is of two types: *polydisc* and *monodisc*. In polydisc strobilation several ephyrae are formed. In monodisc strobilation only one ephyra is formed and it takes during unfavourable conditions.

Sometimes scyphistoma does not undergo strobilation. It gets detached and changes into a single free-swimming ephrya that undergoes metamorphosis into a medusa.

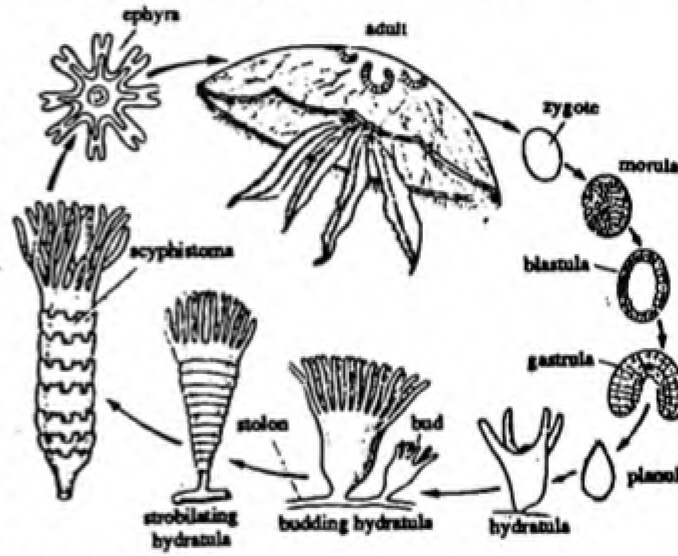


Fig. 26.12 Life-history of *Aurelia*.

Ephyra. The *ephyra* is a young medusoid form showing tetramerous symmetry. Its margins has four per-radial and four inter-radial befid arms. Each arm is deeply notched distally to form marginal lappets. The groove between them is sensory in nature and has a short tentacle which later becomes tentaculocyst. The larva has a small stomach with gastric filaments (which are derived from mesenteries), a manubrium and a rectangular mouth on the subumbrellar surface. The stomach gives off canals which pass into the arms. These canals represent per-radial and inter-radial canals. The ad-radial canal appears a little later.

Metamorphosis of ephyra into *Aurelia*. The ephyra swims actively in sea water feeding on minute organisms such as protozoans which are caught by the lappets and passed into the mouth. It grows in size. The mesogloea increases so that the two layers of endoderm together to form an endodermal lamella except the enteron. The ad-radial region grows more rapidly and fills their clefts so that the umbrella becomes circular and saucer-shaped and resembles the adult medusa. Now the four oral arms and numerous marginal tentacles appear so that the ephyra is finally transformed into an adult *Aurelia*.

It has been seen that very large eggs of *Aurelia* develop into *actinula larva* which gives rise to ephyrae larvae directly. The small eggs give rise to *planula larvae* which become hydratubae and then scyphistomae which strobilate ephyrae.

Alternation of Generations

The life cycle of *Aurelia* is said to show alternation of generations. The adult medusa represent the sexual phase producing gametes. The zygote produces fixed scyphistoma (polypoid) which represents the asexual phase resembling the polyp of *Obelia* colony. The scyphistoma reproduces asexually by strobelation to form ephyrae which metamorphose into adult *Aurelia* which is a sexual form.

According to some workers, the development of *Aurelia* does not show true alternation of generations. The adult *Aurelia* medusa is formed by the metamorphosis of an ephyra larva produced as one of the several transverse segments of the polypoid scyphistoma, whereas in *Obelia* the medusa is developed as a bud on a branched polypoid colony. In *Aurelia* the polypoid phase is greatly reduced in the life-cycle. As the medusa is formed by the metamorphosis of an ephyra and the life-cycle is continuous process so that there is no metagenesis or alternation of generation.

Comparison between *Obelia* and *Aurelia*

Obelia	*Aurelia*
Polyp	
1. It is one of the zooids of a polymorphic colony.	1. It is a larval stage in the life history.
2. The adult is covered with perisarc.	2. Perisarc is absent.
3. It is formed as a bud on the colony.	3. It develops from zygote.
4. Blastostyle directly produces medusa by budding.	4. Scyphistoma produces ephyrae by strobilation which metamorphose into medusae.
5. There are no gastric ridges or mesenteries so that the enteron is undivided.	5. Body wall projects into enteron as four longitudinal septa, the mesenteries, along interradii.
6. It is meant for feeding and defending the colony.	6. It is meant for asexual multiplication.
Medusa	
7. Medusa phase is reduced and known as swimming bells.	7. Medusa phase is dominant and known as jelly fish.
8. It is very small in size measuring 6 mm. in diameter.	8. It is large and measures upto 4 inches or 30 cm.
9. The oral arms are absent.	9. Four oral arms surrounding the mouth.
10. Manubrium is long	10. It is short.
11. Bell margin is not scalloped.	11. Bell margin is scalloped, having eight notches for tentaculocysts.
12. Bell margin beset with few long solid tentacles.	12. Bell margin beset with many small, hollow tentacles.
13. True velum is present, projects inwards from bell margin and lacks endodermal canals.	13. True velum is absent, inconspicuous velarium present containing endodermal canals.
14. Sense organs are ad-radial in position, lie at the bases of the tentacles, are without protective lappets and hood. These are purely ectodermal sacs and are called statocysts.	14. Sense organs are per-radial and inter-radial in position, lie in the marginal notches, are protected by lappets and hood, enclose gastrodermal canal and are called rhopalia.

Obelia	Aurelia
15. Canal system simple, stomach not well defined. Gastric pouches are absent. Canals unbranched.	15. Canal system complicated stomach specious. Gastric pouches are present, canals are branched.
16. Gastric ridges and filaments absent.	16. Gastric ridges bearing filaments are present.
17. No current of water circulates in the canal system.	17. Water circulates in a definate course in gastrovascular system.
18. Mesogloea non-cellular.	18. Mesogloea contains amoeboid cells and fibres.
19. Muscle strands derived from both ectodermal and endodermal cells.	19. Muscle strands derived only from ectoderm.
20. There is a double nerve ring in the margin of the bell.	20. There is no double nerve ring in the margin of bell. Instead there are 8 separate nerve centres besides the sense organs.
21. Nematocysts confined to the manubrium and tentacles only.	21. Nematocysts are present all over the bell, manubrium, oral arms and gastric filaments.
22. Nematocysts are only one type *i.e.* penetrant type.	22. Nematocysts are of two types, atrichous isorhizoas and heterotrichous microbasic euryteles.
23. Gonads lie on radial canals externally	23. Gonads lie on the floor of gastric pouches internally.
24. Gametes derived from ectoderm.	24. Gametes derived from endoderm.
25. Subgerminal pits are absent.	25. Subgerminal pits are present below gemetes.
26. Gametes are shed in sea water by the rupture of gonads.	26. Gametes are shed in the gastric pouches, from where they escape into the sea water.
Development	
27. Fertilization is external.	27. Fertilization is internal.
28. Cleavage is holoblastic equal.	28. Cleavage is holoblastic but unequal.
29. Gastrulation by delamination.	29. Gastrulation by invagination.
30. Planula large is without blastopore and coelenteron.	30. Planula larva has blastopore and coelenteron.
31. Planula forms hydrula stage which produces *Obelia* colony by budding.	31. Planula forms trumpet-like scyplistoma which forms ephyrae by strobilation.
32. Life-cycle shows metagenesis.	32. No alternation of generations in the life cycle.

27

METRIDIUM

Sea-anemones are among the most beautiful and prominant animals of the sea-shore. They are brightly coloured and when fully expanded, turn the sea-floor into a flower-bed. When disturbed these sensitive animals contract to shapeless mass.

SYSTEMATIC POSITION

Phylum	-	Coelenterata
Class	-	Anthozoa
Subclass	-	Hexacorallina
Order	-	Actiniaria
Genus	-	*Metridium*

HABITS AND HABITAT

The sea-anemone is a large, sessile, marine polyp. It has a thick columnar body and numerous short tentacles. There is no trace of a medusoid stage in the life-cycle. It occurs commonly on rocks, weeds, shells etc. It occurs from tide pool to a depth of 90 fathoms. It is found from New Jersey as the variety *M. marginatum*. This form also occurs on the coast of Europe. Another species, *M. fimbriatum* extends the range of the Pacific. It is solitary and plankton feeder. It reproduces sexually as well as asexually. Development indirect through a planula larva.

EXTERNAL FEATURES

Shape, Size and Colouration. It has a stout, cylindrical body with a crown of tentacles. It measures 5-7 cm in length. Sea-anemones are often brightly coloured. They may be white, green, blue, orange or red or a combination of many colours.

Divisions of Body. The body is divisible into three parts:

(i) Oral disc (ii) Coloum (iii) Pedal disc.

(i) *Oral disc.* It is the upper or distal free end of the body. It expands horizontally to form a round saucer-shaped *peristome* or *oral disc.* Many small and hollow tentacles are present along its margin in the form of a crown. These tentacles are arranged in several circles around the slit-like mouth present in the centre of the oral-disc. Generally, the number of tentacles in each circle is in the multiple of six. Their number increase with the age. The tentacles posses nematocysts.

(ii) *Column.* The upright part of the body is called column. The junction of the oral disc and the column is called the *margin* and it may be marked by a groove. The surface of the column is beset with adhesive warts or papillae by whose secretions the animal gets the stones, sand and shells attached to its body surface and gets completely hidden from view. The wall of the column may vary from thin transparent to thick leathery condition. The column may be differentiated into an upper short region the *capitulum* and a lower thick walled region, the *scapus.* Scapus just before joining the capitulum stands up as a distinct fold, the *collar* or *parapet*, and a groove called *fossc* results between the collar and base of the capitulum. Irrespective of the presence or absence of the capitulum the upper part of the scapus may be differentiated into a short region, the *scapulus.* Just below the margin or at the lower boundary of capitulum there is the marginal *sphincter.* This acts to close the margin or upper end of the scapus over the retracted oral disc or capitulum when sea-anemone contracts. The sea-anemone having parapet, the sphincter is in the wall of the fosse. The wall of the column presents a variety of special structures or protuberances which may be ornamented with adhesive or protective papillae. Thus they cover themselves by sands and

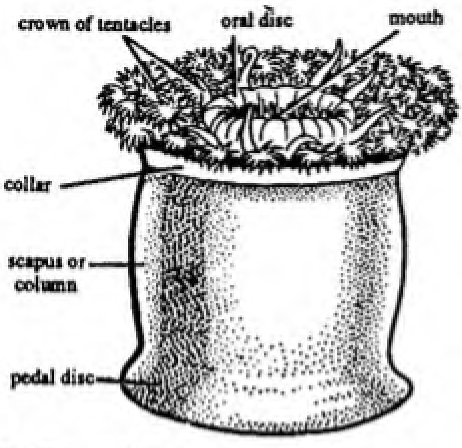


Fig. 27.1 *Metridium.* External view.

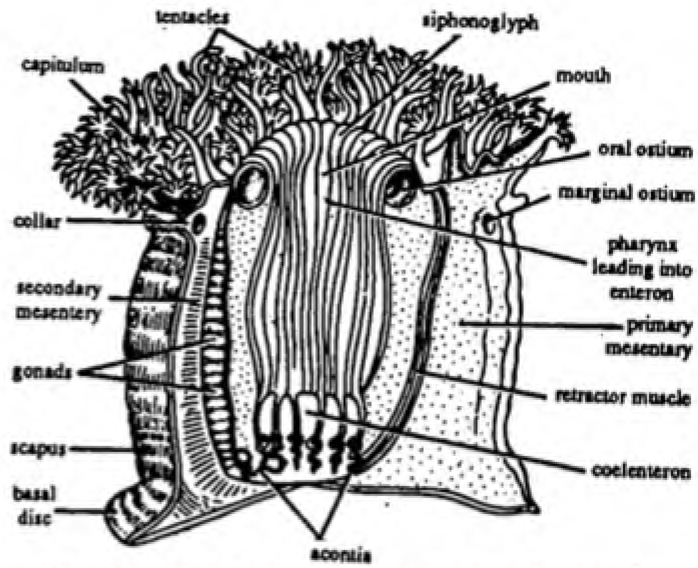


Fig. 27.2 *Metridium.* Vertical longitudinal section to show internal structure.

stones. These papillae may be arranged in rows. In some of the sea-anemones the column wall is provided with a number of pores, called as *cinclides* through which *acontia* protrude out. They also serve for the expulsion of water when the column contracts.

ii) *Pedal disc.* The base is demarcated externally from the column by a groove, the *limbus*, and is expanded to form a circular pedal disc for attachment to the substratum. The animal is not sedentary because it can creep by gliding motion of the basal disc which puts out a turgid lobe in the direction of movement while the opposite end contracts. The speed of its movement is about 8 cm. per hour.

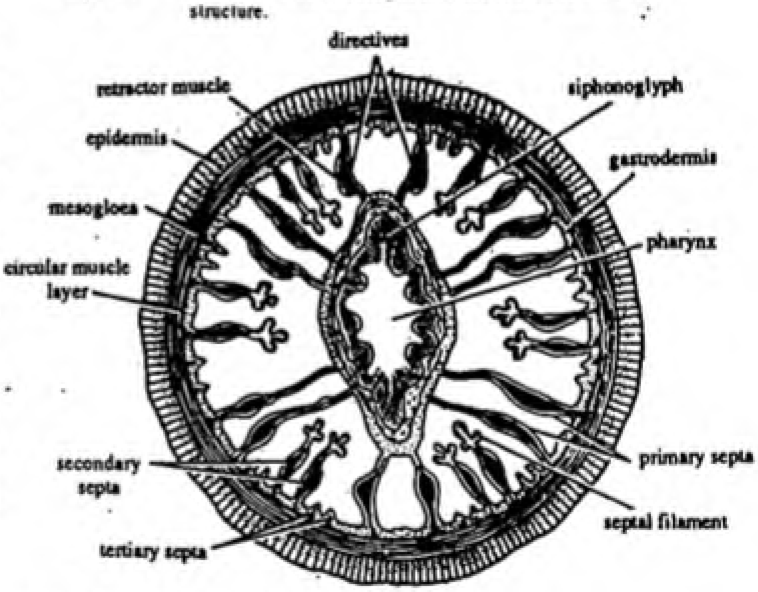


Fig. 27.3 *Metridium.* T.S. through pharynx showing measenteries.

INTERNAL STRUCTURE

The internal structure of a sea-anemone can be studied by cutting it longitudinally, through the mouth, and transversely.

Enteric cavity or gastro-vascular system. The mouth opens into a muscular, flat, tube-like *gullet* or *pharynx.* It is formed by the inversion of the wall of the oral disc. Gullet extends downward and opens into the central part of enteron or gastro-vascular cavity. The pharynx or stomodaeum extends to about 2/3 of the length of the body and is lined with ectoderm. The free lower end of stomodaeum is produced at each end of the long diameter into *lappet.* At one end or both the ends of the long diameter of stomodaeum there is a longitudinal ciliated grove, the *siphonoglyph.* Specimens with one and two siphonoglyphs are called *monoglyphic* and *diglyphic* respectively. If there are two siphonoglyphs, the major one is called *sulcus* and the other is *sulculus.* This variation in the number of siphonoglyphs in *Metridium* is probably due to asexual reproduction or regeneration after injury. The presence of siphonoglyph breaks the radial symmetry of the animal and it appears bilateral. This type of symmetry is called biradial symmetry. Sometimes specimens are without siphonoglyph or three siphonoglyphs.

The enteron or gastro-vascular cavity is divided into a number of raidally arranged cavity by vertical partitions that extends from the body wall inwards to varying distances. These partitions are called *septa* or *mesenteries* and the cavities between them are *intermesenteries chambers*. The chambers between the mesenteries of some pair are called *endocoels* and the chambers between the adjacent mesenteries are called *exocoels*.

All the mesenteries are not equal and are arranged in pairs. On one side of each septum runs a longitudinal retractor muscle. These muscles can cause great contraction of the animal so that water ejected through mouth. Some of the mesenteries are more broad and longer and reach the stomodaeum. These are called *primary, complete* or *perfect* mesenteries. There are usually six pairs of primary mesenteries in *Metridium*.

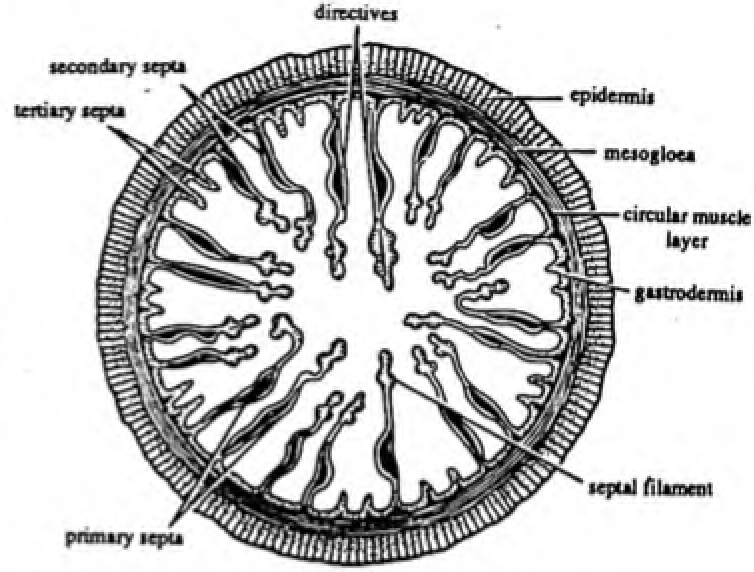


Fig. 27.4 *Metridium*. T.S. below the pharynx showing mesenteries.

A little short and incomplete *secondary* mesenteries are found in between the pairs of primary mesenteries. More small pairs of *tertiary* mesenteries also found between them. These are attached to the body wall but do not extend up to the stomodaeum. In *Metridium*, the position of siphonoglyph and mesenteries becomes much irregular due to asexual reproduction. The chambers between the primary mesenteries are in open communication with each other only below the stomodaeum. In stomodaeum, the adjacent chambers communicate with each other only by one or two apertures, called *ostia*. The ostia found on the outer side of the mesenteries are called *marginal ostia*, while those found on the gullet side are known as *oral ostia*. In secondary mesenteries only marginal *ostia* are found. The cavities of the tentacles also open into intermesenteric chambers.

Each mesentery has two layers of endoderm. Mesogloea is present between these two layers. These increase surface area for digestion.

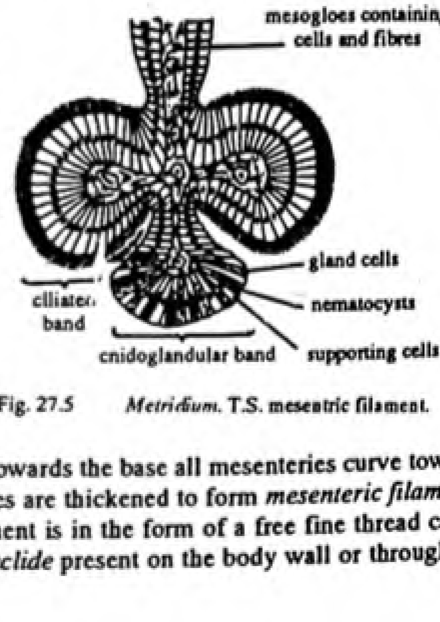


Fig. 27.5 *Metridium*. T.S. mesentric filament.

Below the gullet, the primary mesenteries curve away from the centre and towards the base all mesenteries curve towards the centre, reaching various points on the base. The free-edges of the mesenteries are thickened to form *mesenteric filaments*. These are trifid in the region of gullet. The lower part of each mesenteric filament is in the form of a free fine thread called *acontium*. The acontia can be protruded through the special apertures called *cinclide* present on the body wall or through the mouth. Nematocysts and gland cells are also found in acontia.

HISTOLOGY

The body wall consists of the usual two layers, *epidermis* and *gastrodermis* with an intermediate layer of *mesogloea*.

(i) **Epidermis.** It is made up of columnar supporting cells containing between them slender sensory cells, mucous secreting gland cells and cnidoblasts. The supporting cells are ciliated on the tentacles and oral disc. The sensory cells are numerous in the tentacles, oral disc and stomodaeum but they decrease in the column and again abundant in the basal disc.

(ii) **Gastrodermis.** It is made up of epithelio-muscular cells in which the bases of cells are drawn out into the muscle fibres, these muscle fibres are circular in tentacles, oral disc, column and basal disc. On the mesenteries they form strong retractor muscles which run longitudinally. Between the epithelio-muscular cells are granular, gland cells which secrete enzymes. Sensory cells and nematocyst on mesenteries are also found. The cnidoblasts and gland cells are confined to the middle lobe

of the trilobed mesenteric filaments. These lobes are, therefore, known as *cnido-glandular bands*. The lateral lobes bear cilia, hence called *ciliated bands*.

(iii) **Mesogloea.** It is the intermediate layer, thick and tough. It has the form of connective tissue. It consists of matrix with amoebocytes and abundent fibres.

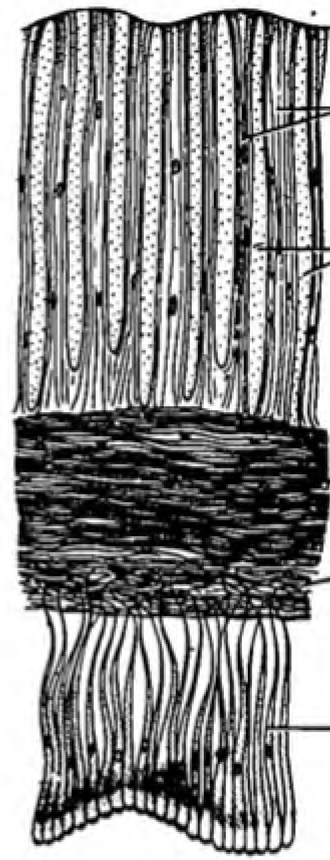


Fig. 27.6 *Metridium*. Transverse section.

NEMATOCYSTS

Metridium has four types of nematocysts. These are usually slightly curved and without a cnidocil.

(i) **Spirocystis.** The spirocysts has a thin single-walled capsule and spirally coiled, unarmed tube or thread of uniform size. The capsule contains mucoprotein or glycoprotein. These are found on oral disc and tentacles.

(ii) **Basitrichous isorhizas.** It has oral capsule containing a mixture of phenol and proteins. The thread or tube is of uniform size and armed with spines. It remains open at the tip. The butt is absent.

(iii) **Microbasic mastigophores.** It has rounded capsule, the but is long and bears spines in a spiral. The thread is long and closed at the tip.

(iv) **Microbasic amastigophores.** It has an oval capsule with a short but armed with spines in a spiral. Thread is absent.

The last three nematocysts are found everywhere on the body.

Arrangement of muscles. It will be seen from the general account of the anemone given above that it has a structure of a large and elaborate polyp. Due to its complicated structure, it can perform various kinds of movements. It can expand or contract the column greatly, can bend or stretch the tentacles and can evert wholly or partly the stomodaeum, acontia and mesenteries. Besides, like the *Hydra*, it can creep slowly on its base. All these movements require well developed muscles, most of which are found in connection with the mesenteries. The most important and conspicuous of these muscles are the longitudinal muscles running the entire length of the mesenteries on one of their faces. These are *retractor muscles* and when they contract, the length of the mesenteries, as well as the body itself, is considerably reduced. These also cause the contraction of the tentacles. Another set of muscles passes obliquely across the upper and lower inner angles. These are *parietal muscles* and by their contraction the column is drawn towards the base. A third set of mesenteric muscles consists of *transverse muscles* and runs at right angle to the longitudinal muscles. These are comparatively weak and oppose the action of the longitudinal muscles and reduce the diameter of the animal to some extent. There are also circular fibres making a sphincter at the junction of the column and oral disc which help to retract the oral disc and the tentacles by their contraction. Besides, these, are muscles in the tentacles, gullet, etc. It has been stated that the longitudinal muscles stretch on a particular face of the mesentery. The oblique muscles also run on the same face, but their arrangement on the different mesenteries is not arbitrary. On the other hand, they have a regular arrangement which, along with the compressed nature of the gullet and the presence of the siphonoglyphs imparts a distinct bilateral symmetry to the animal.

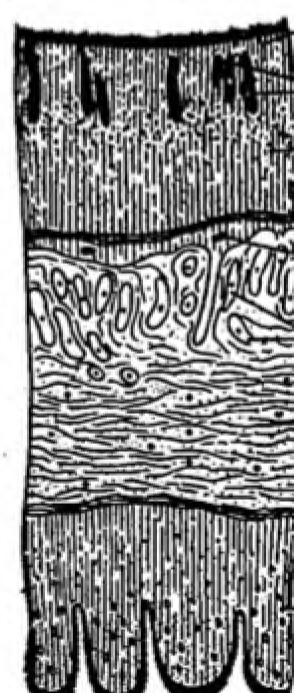


Fig. 27.7 T.S. of tentacle of *Metridium*.

The mesenteries are always present in pairs and the pairs of mesenteries

corresponding to the siphonoglyphs are called *directive mesenteries*. In the directive mesenteries, the muscles face away from each other. In the other pairs of mesenteries, whether primary, secondary or tertiary, the muscles face towards each other.

NERVOUS SYSTEM

Specific sense organs do not occur in anemones. The nervous system is very simple, basically similar to that of other coelenterates, and is *synaptic*. It is represented by a typical diffuse *nerve-net* with no indication of a centralized nervous control, as in medusae. It consists of an *epidermal plexus*, between the epithelium and muscular layer, and a *gastrodermal plexus*, at least in the septa; the two are connected through the mesogloea. Each plexus consists of delicate *nerve fibres* and large *ganglion cells* occurring chiefly in the tentacles oral disc and pharynx. The reflex behaviour is poor due to lac of a centralized nervous system.

PHYSIOLOGY

Movements. They are inactive animals but due to development of musculature they show following movements:

(i) The column can be expanded or retracted.

(ii) Tentacles extend to a considerable length or may be completely retracted back and become hidden by the upper end of the column which becomes folded over them.

(iii) Stomodaeum and septa may be partially everted through the mouth.

(iv) It can slowly glide on the substratum and by slow cleeping movements can change its position. This is brought about by muscular undulations of pedal disc. The movement is very slow about 8 cm/hr.

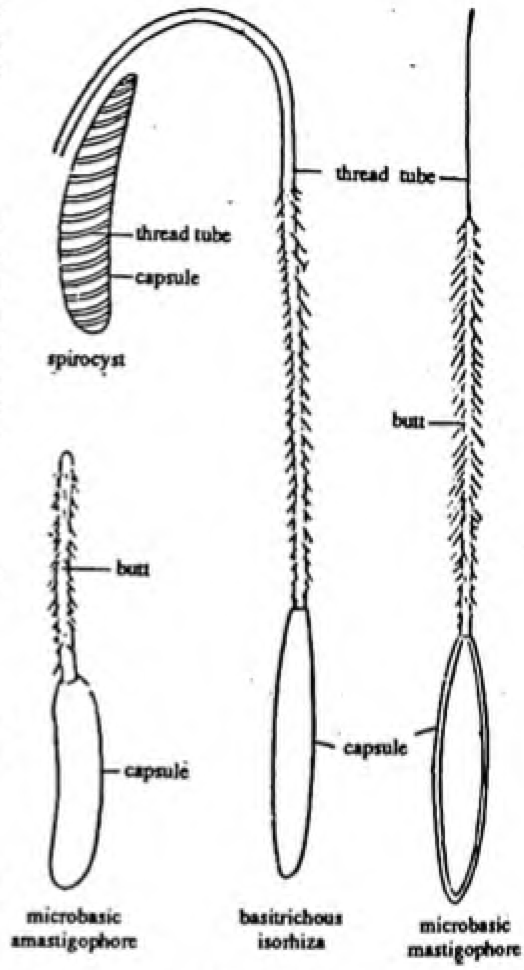


Fig. 27.8 *Metridium*. Types of nematocysts.

Nutrition. The animal is quite voracious, and feeds on molluscs, crustaceans, worms, sea-urchins and fishes, etc. The prey is captured and partly paralysed, before ingestion, by the nematocysts of tentacles, oral disc and acontia. Mouth opens and the gullet protrudes out as small lobe. The part of the oral disc between the food and the mouth contracts so that the lobes of the gullet reach the food and grasp it.

Most of the smaller sea-anemones are ciliary feeders. Cilia on the outer surface of the column beat towards the oral disc, where ciliary currents sweep the food particles to the tips of tentacles. The latter-bend down to transfer the food into the mouth. Mucous and nematocysts play an important role in capture of the planktonic organisms. The captured food is swept down the stomodaeum into the gastrovascular cavity.

In the gastrovascular cavity the prey is killed, if still alive, by nematocysts and is subjected to *intercellular digestion*. The latter reduces the food to pieces under the action of a protease of the nature of trypsin secreted by the gland cells of the cnido-glandular bands of the mesenteries. The pieces are then engulfed by the gastrodermal cells, except those of the cnido-glandular bands, for *intracellular digestion*. The latter is brought about by proteases of the nature of pepsin and erepsin and lipases. Carbohydrates are perhaps not utilized by the sea-anemone.

The digested food is absorbed in the gastrodermis while the undigested food is ejected out through the mouth.

The excess food is stored in the gastrodermis chiefly as fat. The sea-anemone can live without food for a long time, utilizing its reserve fat.

Respiration and Excretion. Respiration is aerobic. Epidermis and gastrodermis are in contact with water. With the result,

oxygen of the water easily diffuse into the cells and the carbon dioxide of the cells diffuses into the water. Definite respiratory currents are maintained to renew water in the enteron. The cilia of the siphonoglyphs beat inwards and those of the rest of the gullet beat outwards. This makes the water current enter through the siphonoglyphs and leave through the gullet. Water inside the enteron is circulated by gastrodermal cilia. Ammonia is the chief nitrogenous waste product it is diffused out in the surrounding water.

REPRODUCTION

Metridium reproduces both asexually as well as sexually.

I. **Asexual Reproduction.** It takes place by following methods.

(a) *Pedal Laceration.* Pedal laceration is the predominant mode of asexual multiplication. In this process, parts of the pedal disc may firmly adhere to the substratum and get torn off as the anemone creeps along. These pieces in a few days develop into small new anemones at the old site and the parent completes its pedal disc at a new place. Or, alternatively, small lobes arise from the margin of the pedal disc and get constricted off. These are carried by water current to new places where they give rise to young anemones.

Fig. 27.9 *Metridium* showing longitudinal; binary fission.

(b) *Longitudinal Binary Fission.* The pedal disc elongates in the sagittal plane till it ruptures along the transverse plane. The cut then rapidly extends upwards through the column and the oral disc.

(c) *Budding.* It involves formation of outgrowths from the column or pedal disc and their transformation into new individuals. The latter ultimately detach from the parent and establish themselves at new places. Budding is of rare occurrence.

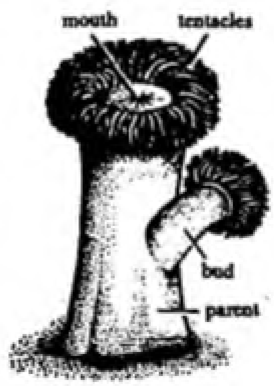


Fig. 27.10 *Metridium* showing budding.

II. **Sexual reproduction and life cycle.** Sea-anemones are dioecious or unisexual. Near the edges of the septa or mesenteries and lying parallel to them, gonads are located. The sex cells are gastrodermal interstitial cells that ripen in the mesogloea. Eggs are spermatozoa produced by gonads are discharged into gastrovascular cavity and finally pass out in sea water through mouth. Fertilization is external and takes place in sea water. Zygote develops after undergoing total, unequal or equal cleavage in a *coeloblastula*. The endoderm is formed by invagination. The embryo elongates into a ciliated *planula* having in some forms an aboral large hard tuft of cilia. At the oral (posterior) pole the blastopore persists in cases of invagination or soon breaks through. Then blastopore becomes the lower opening of stomodaeum. The planula larva swims for some time and feeds on micro-organisms. Finally it settles down at the bottom of the sea and attaches itself by aboral end. The tentacles, septa and mesogloea are formed and the planula larva changes into a minute animal.

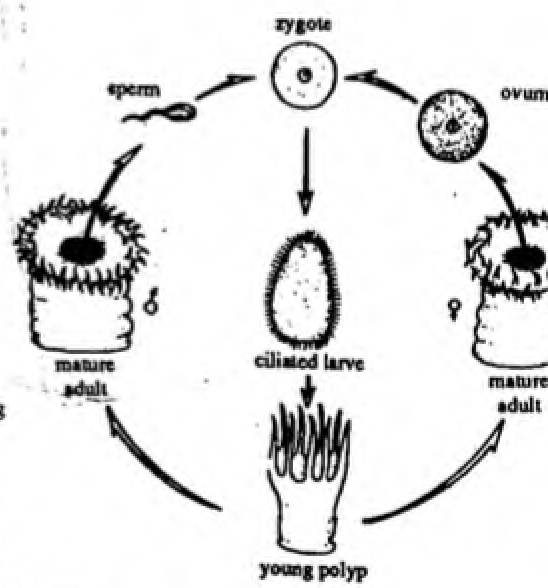


Fig. 27.11 *Metridium*. Life-history.

REGENERATION

Metridium has a power of regeneration. If the column is cut across, the aboral part regenerates a new oral disc but the oral part fails to develop a pedal disc. In some cases, instead of a new pedal disc, the oral part regenerates a second set of tentacles at its lower aboral surface. Thus it exhibits a case of *hetermorphosis* or reversed polarity.

Differences between Hydrozoan polyp and a Sea-anemone

Hydrozoan Polyp	*Sea-anemone*
(*Hydra*)	
1. Fresh water.	1. Marine.
2. Body long, slender and delicate. .	2. Body large, heavier and firm.
3. Mouth circular and at the tip of a conical manubrium.	3. Oral cone is absent and mouth is slit-like at the centre of a horizontal disc.
4. Tentacles less, long, arranged in a ring, at the base of manubrium.	4. Tentacles numerous, short, usually arranged in multiple of six, on the oral disc.
5. Column without pore.	5. Column with numerous pores, the cinclides
6. Mouth directly leads into the gastro-vascular cavity.	6. Mouth leads into a long flattened gullet or stomodaeum lined by ectoderm.
7. Gastrovascular cavity specious, undivided.	7. Gastrovascular cavity is divided into a number of chambers by mesenteries.
8. Mesogloea is thin and without any cell.	8. Mesogloea with fibres and amoebocytes in a gelatinous matrix.
9. Nematocysts are four types: penetrants, volvents, holotrichous isorhizas and atrichous isorhizas. They posses operculum and cnidocil.	9. Nematocysts are four types: spirocysts, basitrichous isorhizas, microbasic mastigophores and microbasic amastigophores. Operculum and cnidocil are absent.
10. Musculature less developed.	10. Musculature well developed.
11. Asexual reproduction by budding only.	11. Asexual reproduction by pedal laceration, budding and longitudinal fission.
12. Gonad develop externally are ectodermal in origin.	12. Gonad develop internally on mesenteries are gastrodermal in origin.
13. Gastrulation by multiple ingression followed by delamination.	13. Gastrulation by invagination.
14. Resting cysts are formed during unfavourable conditions. Dispersal by these cysts.	14. No cyst formation.
15. Planula larva is absent.	15. Planula larva is present and dispersal by these larvae.

28

CORAL AND CORAL REEFS

Corals are a group of marine coelenterates which are mostly colonial but some are solitary and occur only in polyp stages. Most (tree corals) of them belong to the order Madreporaria but some others belong to subclass Octocorallia.

Besides a group of Hydrozoa, the *Millepora* and its allies also are called corals due to their skeletal structure but they have no rel similarity with true corals. Since the true corals are the builders of coral reefs and island so only the Madreporariana corals are considered here.

DEFINITION OF CORAL REEF

Vaughan (1917) has defined a coral reef. "A coral reef is a ridge or mound of limestone, the upper surface of which is near the surface of the sea and which is formed of calcium carbonate by the action of organism chiefly corals". *Bayer* and *Owre* (1969) mention, "The uppermost layer is a living stratum composed of growing corals, alcyonarians, and millepores, together with a virtually endless array of other organisms that live on or in this frame work, some acting to break down the coral skeletons, others serving to cement the resulting debris together into a conglomerated mass that can act as a foundation for further coral growth. Boring sponges molluscs, worms, and barnacles permeate the coral substance and open it to erosional forces that weaken it until it crumbles. Algae, sponges, hydroids, tunicates and other organisms, as well as chemical process, consolidate the fragarments and provide a platform for new growth."

REQUIREMENTS AND DISTRIBUTION

The reef-building corals require warm, clear, shallow water. Therefore, they are confined to continental and island shores in tropical regions (latitude 28°N-28°S). They flourish best at temperature between 22°C-28°C. As temperature falls with an increase in the depth o sea water, the reef building corals occur up to a depth of 30 metres, or at the most 50 metres. They inhabit water subject to strong wave action, because they cannot remove large amounts of sediment likely to accumulate on them in quiet waters. Excessive rains and fresh water are harmful for corals.

The reef building corals are found in two general regions: (i) the *Caribbean waters* including Florida, Bermuda, the Bahamas, and the West Indies; and (ii) the Indo-Pacific water from the east coast of Africa through the Indian Ocean and the Western Pacific as for as Hawaii. The second region specially abounds in coral reefs, and in fact the Pacific north-east of Australia is known as the coral sea.

Fig. 28.1 Distribution of *coral reefs* today (heavy shading).

CLASSIFICATION OF CORALS

The Madriporarian corals are divided into three groups:

1. **Imperforate or Aporous Corals.** They have a complete theca, compact sclerosepta and partitioned into loculae e.g., straeid corals, *Favia, Flebellum* (= *Meandrina*, brain corals).

2. **Perforate corals.** In these corals the corallum is extremely porous everywhere and is of loose construction e.g. *Porites, Acropora* (= *Madrepora*), *Montipora.*

3. **Fungid Corals.** These may be either perforate or imperforate e.g., Fungia.

Corals can also be classified as follows:

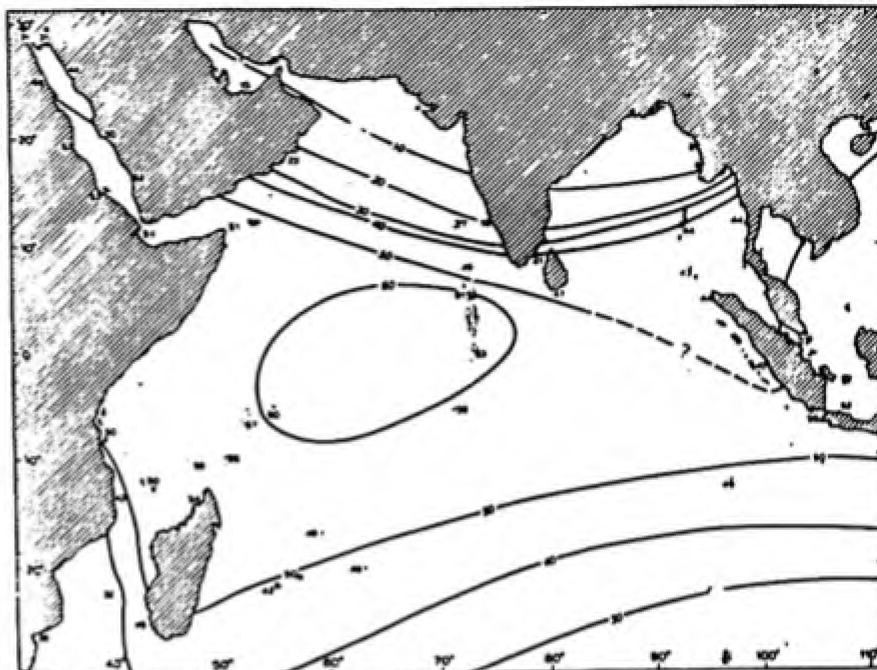


Fig. 28.2 Diversity of *corals* in the Indian Ocean. Contour lines indicate predicted numbers of genera based on actual collection. The numbers decline with increasing latitude and lower water temperatures. Latitude and longitude are given in vertical and horizontal margins.

(a) *Hydrozoan corals.* Some of the animals such as Millepora, Stylaster etc. (belonging to the order Hydrocorallina) are colonial and are surrounded by calcarcous exoskeleton. The skeleton is secreted by ectoderm. The individual has two types of polyps namely gastrozooids and branched dactylozooids loged within the exoskeleton. The dactylozooids are arranged around the central gastrozooid. The help in the formation of coral-reefs.

(b) *Octocorallian corals.* These include soft corals. The coral is formed of a colony of polyps with endoskeleton of separate calcareous spicules embedded in the massive mesogloea. In the colonial coral, *Tubiproa* or organ-pipe coral, the skeleton is made of calcareous spicules consisting of vertical tubes connected together by lateral platforms. The vertical tubes are also partitioned by smaller cross plates. The tubes contain polyps. In *Haliopora* or blue coral, the calcareous spicules form a massive skeleton of corallium. In *Gorgonia* or sea fan, the colony branches in one plane and the axial skeleton is made up of horny material intermixed with calcareous spicules arranged around the polyps.

(c) *Hexacorallian corals.* These constitute the *stony corals* or *true corals.* They may be solitary or colonial and assume a great variety of forms. They are the main constituents of coral reefs.

Solitary corals. *Fungia, Flabellum, Caryophylla*, etc. are the solitary corals or cup corals. The corallite is disc-like, cup-like or mushroom-shaped in form and measures 5 mm. to 25 cm. across. It is often without a theca.

Colonial corals. Majority of the stony corals is colonial with plate-like, spherical cup-like or vase-shaped skeleton (corallium). The typical examples of colonial corals are *Acropora, Oculina, Favia, Madrepora, Meandrina*, etc. The colony is produced by asexual methods from a single sexually produced polyp. The polyps live at the surface of the calcareous skeleton. Depending on the various methods of asexual budding, varying forms of colonies are produced. Some of the colonies are branched. In *Acropora*, there is always a primary polyp at the top of the colony with lateral branches on either side. In some corals, like *Oculina*, the polyps remain widely separated, each occupying a separate theca. In others, like *Favia* and *Astraea*, the thecae are so close together as to have common walls. In the brain-coral, *Meandrina*, the polyps as well as the thecae become confluent, occupying valleys separated by ridges, on the surface of the corallium.

Abode of Animals. Coral reefs are the abode of several other animals as there are numerous interstices, cervices and other hiding places together with sheltering branches of the corals themselves. As such sponges, anemones, sea-urchins, starfish, crabs, tubicolous-annelids, holothurians, snails and bivalves all live in coral reefs.

Magnificent colouration. *Hyman* (1940) writes that as coral beds consist of multitude of organisms of varied shapes and colours, viewed through the deep blue water of a lagoon, constitute one of the most beautiful sights in the world, excel the most splendid flower gardens. The coral polyps are yellow, green or brown due to their zooxanthellae but almost any hue can be seen in them. The skeletons of corals are usually white but as they are sometimes permeated with red and green algae whose colours they take.

Coral polyps. The coral organism is a small anthorzoan polyp measuring about 1 cm. in length. It lacks a pedal disc and the oral disc bears tentacles in cycle of six. The pharynx is devoid of siphonoglyphs. The mesenteries follow the hexamerous plan and are restricted to the upper part of the polyp. The muscles are poorly developed.

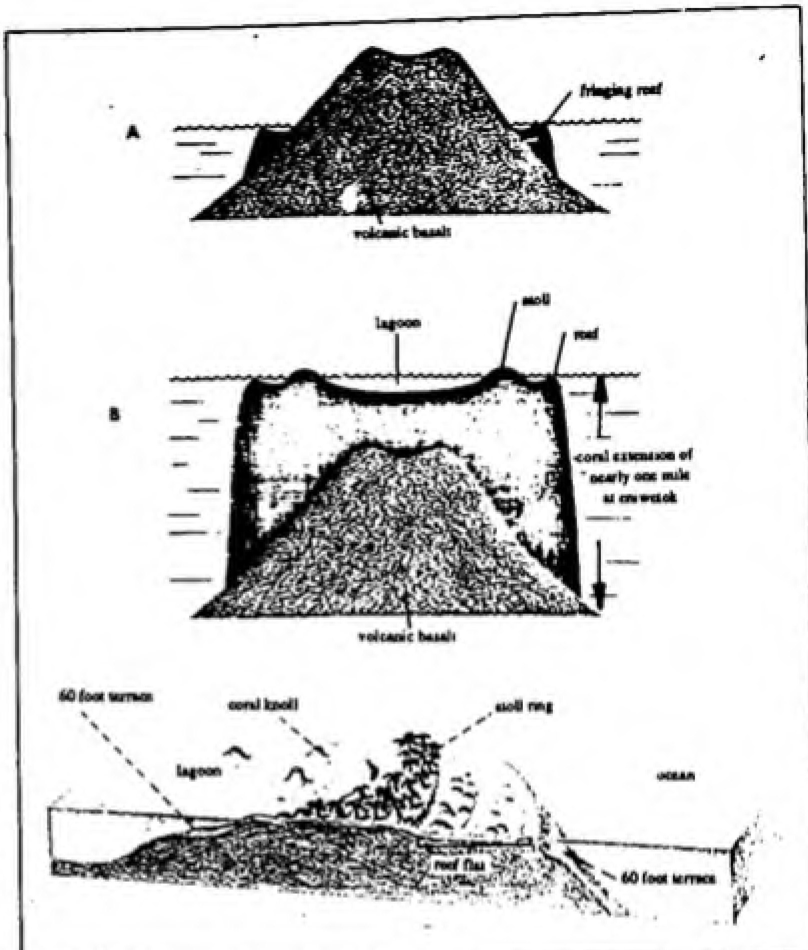


Fig. 28.3 Formation of an *atoll*. A—Fringing reef around an emergent volcano. B—Continuous deposition of coral as volcanic cone subsides leads to the formation of a great coralline cap; emergent part of cap is atoll. C—Section through part of atoll.

Structure of Coral Polyp

In structure the coral polyp is much like an Anemone except the skeletal portions. The structure of the soft part is like sea anemone but pedal disc is absent. Basal region or pedal disc is occupied by skeletal cup. There is no oral cone. Mouth is situated in the middle of the oral disc. A typical oral disc with tentacles on typical hexamerous plan is present. Tentacles are simple and of moderate length ending in terminal knob of nematocysts. A circular mouth surrounded by a flat peristomium leads into short stomodaeum or pharynx devoid of siphonoglyph. There are complete and incomplete septa or mesenteries arranged in cycles arranged on typical hexamerous plan. Coral polyp being small does not possess more than three cycles of mesenteries. Usually two pairs of directives are present and there are ostia on the septa. The polyps of colonial corals are all interconnected but the attachment is lateral rather than aboral, as in hydroids. The column wall folds outward above the skeletal cup and connects with similar folds of adjacent polyps. Thus, all the members of the colony are connected by a horizontal sheet of tissue which represents folds body-wall and so it contains an extension of the gastrovascular cavity as well as an upper and lower layer of endoderm and ectoderm. The lower ectodermal layer secretes the part of the skeleton that is located between the cups in which the polyps lie. The living coral colony thus lies entirely above the skeleton and completely covers it.

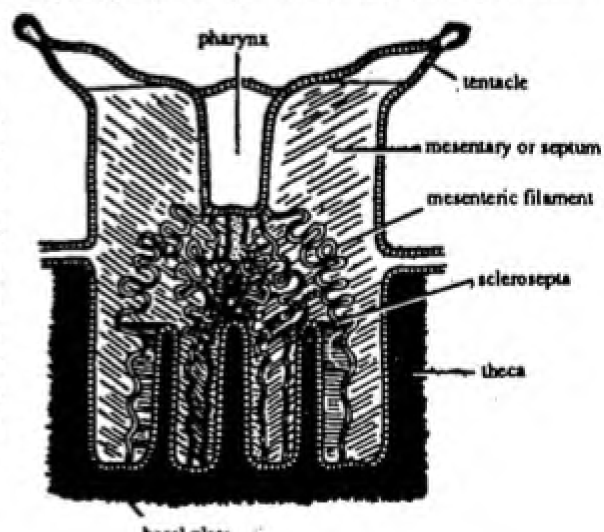


Fig. 28.4 V.S. through a *coral* in its theca (3 sclerosepta are shown)

Structure of Coral Skeleton

The skeleton of a colony is termed as *corallum* and that of coral polyp a *corallite*.

Structure of Corallite. Coral polyps remain fixed in a cup like exoskeleton, the *theca*. The theca and other parts of the skeleton wholly to the outside of the body of the polyp but remain in contact with its ectoderm throughout. According is *Voucoch* the skeleton of coral is made up of calcium carbonate and is formed by the precipitation of calcareous crystals in a calloidal matrix secreted by the ectodermal cells outside the body wall for the protection of the polyp. A typical polyp coral has the following parts:

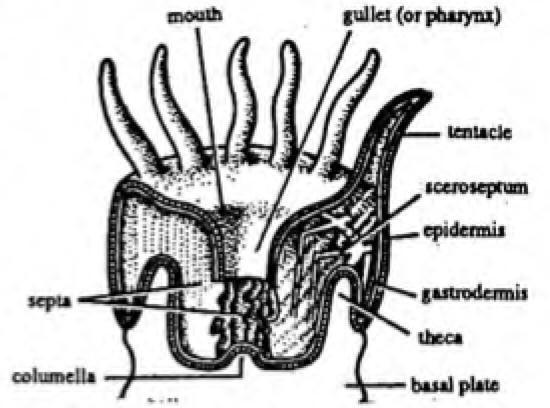
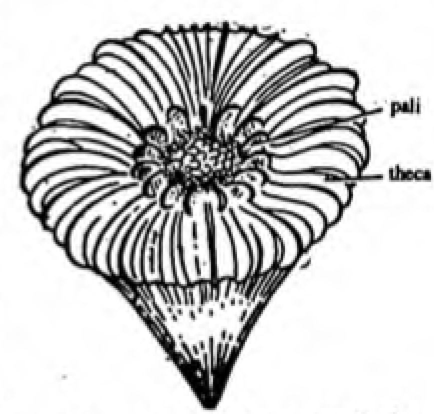


Fig. 28.5 One half of a simple *coral polyp* showing relationship of soft parts of theca (corallite).

1. *Basal Plate.* A basal plate lies between the polyp and the substratum. It is the bottom of the cup.
2. *Theca.* It is a cup like structure from which the polyp projects outside and into which it can be retracted.
3. *Sclerosepta.* These are calcareous ridges or partitions arranged vertically or projecting radially inwards and are connected at the base by basal plate and at the side with the cup like theca. They look like mesenteries but in fact lie between the mesenteries and thus lie in definite relation to them. Like the mesenteries, the sclerosepta typically, occur in hexamerous cycles, 12 tertiaries, 24 quaternaries etc.; but other numbers are also met with. The sclerosepta are usually endocoelic i.e. each skeletal ridge pushes up between the two septa of a pair. The original second cycle is usually, however, exocoelic. The formation of the sclerosepta usually precedes that of the corresponding septa (mesenteries) and thus there are often move sclerosepta than mesentry pairs. The first cycle of sclerosepta reach the columella, while the later one fall short of it and may fuse with adjacent larger sclerosepta. It may be emphasized that the corallite lies entirely outside the body of the polyp and the polyp base is pushed into ridges over the sclerosepta and goes down into blind pockets between sclerosepta and mesentary.

   The sclerosepta are commonly sping thorny with jagged or toothed upper edges.



F 28.6 Theca of a solitary *coral* showing pali.

4. *Columella.* It is a pillar like irregular central skeletal mass which may be eithe an independent outgrowth from the basal plate or one formed by the union of the central ends of the sclerosepta, then called *pseudo-columella*. The columella may be solid or trabeculae.
5. *Epitheca.* It is a distinct calcareous layer which surrounds the base of the theca in a ring-like manner.
6. *Costae.* The space between the theca and epitheca is crossed by continuation of the sclerosepta called costae.
7. *Pali.* Small ridges between the columella and the main parts of the sclerosepta are termed as pali.
8. *Synapticula.* These are the skeletal bars connecting adjacent sclerosepta.
9. *Dissepiments.* Horizontal plates between sclerosepta are known as disepiments. These are of small extent.
10. *Trabeculae.* When the horizontal plates between sclerosepta are large and extend completely the corallite they are termed as trabeculae.

Formation of coral. The coral polyp develops from a planula which settles down and begins to secrete a skeleton rudiment or *prototheca*. It is secreted by eotoderm first as a basal plate. Following it, the larva develops radial folds which secrete septa (sclerosepta) and at the same time a rim is built up as a thecal wall around the polyp, laying at the top. Meanwhile, further skeletal material is added into the gaps between the septa. The septa of the skeleton usually alternate with the mesenteries of a living coelenterate.

In living condition, the polyp fills the whole of the interior of the corallite and projects beyond its edge. The proximal portion of its body-wall is in contact with the theca which is a product of the epidermis. The free part of the body-wall of polyp is folded over the edge of the theca so as to cover its distal portion. Each skeletal septum is covered by an inturned portion of the body-wall.

Thus the septa are actually external and are in contact with the epidermis throughout. The space between the theca of the coral colonies is occupied in like by an extension of the polyp walls, *coenenchyme* continuous with the latter above the upper edge of the theca and containing a gastrovascular space continuous with the latter above the upper edge of walls, *coenenchyme* continuous with the latter above the upper edge of the theca and containing a gastrovascular space continuous with gastrovascular cavity of the polyps. The lower surface of the coenenchyme secretes the part of the corallum between the theca, and this part is called *coenosteum*. In addition, in many corals, the polyps may be connected by canals coming from the bases and passing through openings in the loosely connected constructed thecae. Corals in which the corallite is perforated like this with many openings are termed as *perforate corals* e.g., *Madrepora* whereas those corals in which the corallite are of solid texture and the polyps are connected by coenenchyme only over the upper edge of the theca are called *imperforate* or *porous corals* e.g. *Flabellum, Astraea* etc.

CORAL REEFS

A coral-reef is a ridge of mound of lime-stone, the upper surface of which is near the surface of the sea and which is formed of calcium carbonate by the action of organisms chiefly corals (*Vaughan*, 1917). Though the reefs are built by stony corals but other organisms such as Foraminifera, *Millepora*, tubipores, heliopores, the molluscs, echinoderms, some coralline, algae and sponges contequeute together in the formation of compact structure, the coral reefs. The coral reefs are formed by incrusting their skeletal parts on the deposited lime. Coral reefs composed of multiple of organisms vary in shape and colour. The zooxanthellae is responsible for the rich colouration of corals, which may be brown, yellow, or green. The reef building corals require warm, shallow waters, and consequently are limited to continental island shores in tropical and sub-tropical zones. They cannot tolerate temperatures below 18°C and they flourish nicely only above 22°C. Consequently their distribution is limited to the zone existing between about 28°C on either side of the equator. They rarely remain alive at a depth greater than 4 fathoms.

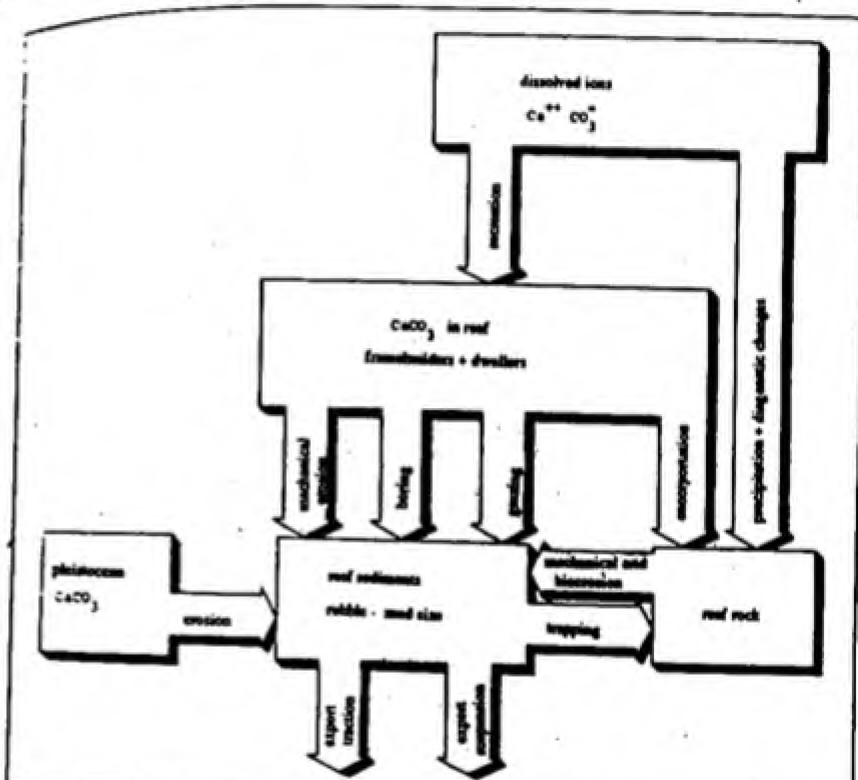


Fig. 28.7 Fate of calcium carbonate on a *coral reef.*

However, none have of the reef types are like man made continues wall but is broken up into many reefs and islands by passages, the larger of which may be drowned valley, sunk bellow the sea by land subsequence or rise in sea level. The lagoons usually contain inner island, or island, and reefs, etc. The flats are move or less exposed exposed at the lowest tides. The reef front is exposed to forceful waves which knock off big and small fragments of the reef and heaves them up on the flat behind the reef edge. The reef front first of all slopes gradually but after about 200 feet the slope becomes very steep.

Types of Coral reefs

Coral reefs are of three types:

(1) fringing reef, (ii) barrier reef and (iii) atoll

(i) *Fringing Reef.* The fringing reefs are sea-level flats starting from the sea-shore and extending for a short distance. They are 1/4 or 1/2 mile in width, built upon the salient parts of continental or insular shores. The fronts of these reefs fall off seaward to moderate depths. They are composed largely of dead reef rock, and are occupied by living reef builders chiefly on their outer edge and slope. Sand and other debris are also found on reefs. Reefs of this kind are quite common in East-Indies.

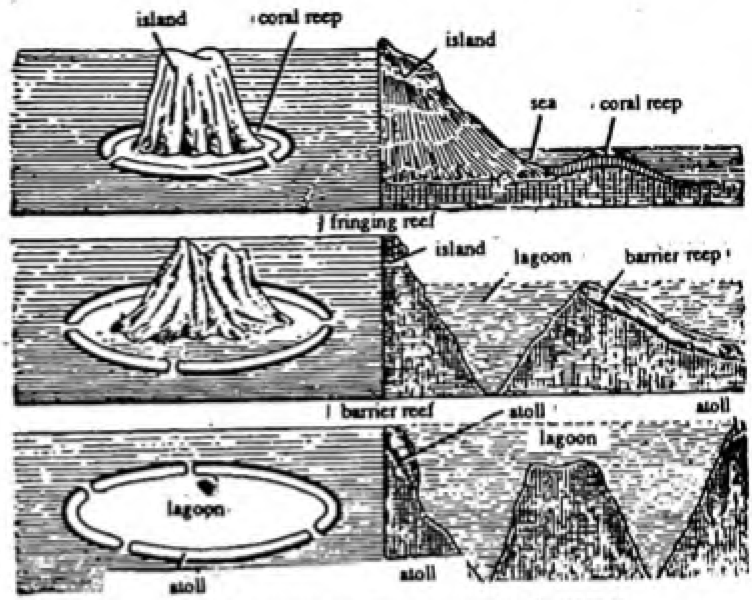


Fig. 28.8 Diagrams of represent different types of *reefs*, entire as well as in cross-section.

(ii) *Barrier Reef.* A barrier reef is like a fringing reef in having a narrow or broad sea-flat and an outer growing face; but differs from it in being separated from the sea shore by a salt water lagoon which is about 1/2 miles to scores of miles in width. The lagoon may be 20 to 40 fathoms or even more in depth. The inner shore is generally occupied by a fringing reef, the growth of which is less vigorous than that of the non-enclosed fringes. The outer or growing face of the barrier is continued in gentle slop 40 or 50 fathoms in depth follow a steep pitch to great depths.

Barrier reefs are frequently interrupted by "*passes*" or *passages* through which even the ships may enter. Barrier reefs may encircle whole islands. Sometimes small islands may make their appearance in the protected lagoons. These reefs are sometimes a great danger to shipping. The Great Barrier reef of north-eastern Australia is about 1350 miles in length, about 20-70 miles wide and encloses a channel from 10 to 25 fathoms deep. At places it is about 90 miles away from the shore. Much of the reef is well below low tide. It is not a single reef but a long string of separate reefs which are not always in a line. Inside the Great Barrier reef are found various types of coral growths. There are hundreds of patches of oral or elongated coral islands built upto the surface. All have their own reefs.

(iii) *Atoll.* It is a coral island and consists of a belt of coral reef having a central shallow lake communicating with the sea. It is a horse shoe-shaped or circular reef enclosing a *lagoon*. These lagoons are 40 or 50 miles across. Several of such atolls occur in the South Pacific. The *Atoll of Bikini* is very famous, which has a land of 287 square miles and a shallow lake of 280 square miles. Another atoll which is very famous due to prominence in World War II, is *Atoll of Tarawa*.

Growth of the coral to form reefs. Rate of coral growth is variable and of great importance. Slow-growing massive types grow 5 mm. per year and fast-growing ones from 10 to 20 cm. per year. *Vaughan* estimated that a reef of 50 mm. deep is formed in 1,000 to 7,000 years and the age of the present reefs is 10,000 to 30,000 years.

Formation

The reefs are largely built by tiny polyps of the stony corals (order Madreporaria). The polyps secrete around them limestone cups, which coalesce to form large masses. The latter, with the passage of time, take the form of huge rocks. Some other animals also take part in the formation of reefs. The hydrozoan *Millepora*, calcified alcyonarians *Tubipora* and *Helicopora* and gorgonians add their skeletons to the reefs. The clams and tubeworms contribute their calcareous shell and tubes to the reefs. Lime secreting algae repair the windward edge of the reef by cementing loose pieces of coral rock into nearly solid rempart. Sinking shells of foraminiferans fill the tiniest pores in the reefs. Whereas some organisms build up the reefs, others, like burrowing animals, break them down. This turns the reefs into labyrinths of ledges, crannies, grottoes crevices and tunnels.

The coral reefs grow very slowly. Most of them expand at the rate of 10-200 mm. per year. The existing reefs seem to have been formed in 15,000 to 30,000 years.

Theories to Explain Great Vertical Thickness of Coral Reef

Since the present reef building corals do not grow below 150 feet at the outside, and because geological evidence indicates that corals of the past ages were also littoral, in their habits, it becomes essential to explain the great vertical thickness often attained by the coral reefs. Many theories have been propounded, which the following four are the main ones:

1. *Darwin's Subsidence Theory.* Charles Darwin's theory explains the formation of reef. According to him the reef begin as fringe around slowly sinking shores, which continue to grow upward and outward as the land sinks. Thus the fringing reef turns into a barrier reef when coast subsidies. The lagoon separating it from the reef becomes wider and wider. Islands surrounded by barrier reefs finally sink beneath the lagoon. Thus the encircling reef is left on which islands of wave tossed. Atolls are formed as accumulation of loose fragments of rocks.

2. *Semper-Murray Solution Theory. Sir John Murray* was the chief biologist on the 'Challenger', the British ship that sailed into the oceans from 1874 to 1876 to explore extensively the conditions and life in the sea. *Murray* proposed that (i) Corals grow on high summits of the ocean bottom when these have been built up to the right level, (ii) the high summits are built by deposition of sediments and (iii) barrier reefs and atolls are formed due to better growth of corals at the reef edge and through solution of the inner coral rock. This theory is now not accepted at all.

3. *Submerged Bank Theory.* This theory has been supported by many recent studies. According to this theory the coral formation grow on flat, pre-existing surface during or after the submergence of surfaces.

4. *Daly-Glacial-Control Theory.* The main points of this theory are as follows: (i) During the last glacial period much water of the ocean turned into ice forming glaciers due to a very low temperature and thus the level of the ocean was lowered by 60 to 70 meters below the present level. (ii) Various terraces were then cut or islands levelled by wave action. (iii) Later, with the rising, temperatures, corals began to grow upon these platforms and kept pace with the rising sea-level as the ice melted.

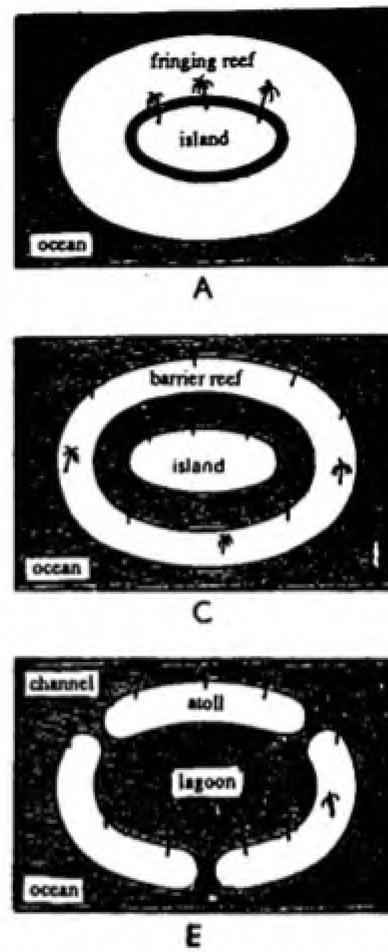


Fig. 28.9 *Coral reefs.* A—Fringing reef. C—Barrier reef. D—Barrier reef in section.

This theory explains nicely about the uniform depth of coral lagoons, whose bottoms, below the debris since deposited, would consist of the platforms cut when the ocean was at its low level.

Theories 3 and 4 supplement each other and at present are most favoured by the students of the problems, although Darwin's idea (Darwin-Dana subsidence theory) continues to find much support. The submergence theory agrees with Darwin's subsidence theory in that both consider the reef foundations to be now at great depths than they were when the coral growth started. But the submergence theory does not admit any relationship between that various kinds of reefs and postulates that the barrier reef and atoll have grown upon pre-existing flat platforms. The atolls are considered to have been shaped by winds, waves and currents.

Boring have been made to find out the truth of these theories.

(i) Boring of Funafuti atoll in the South Pacific north of Fiji was made in 1904 by an expedition of the Royal Society of London. The boring was 3 inches to 5 inches in diameter and went up to 1114 feet without reaching the reef base. Twenty eight genera of reef building corals were discovered, 2 of which are now living on the reef in that locality above 60 metres. The material obtained from the boring did not contain any of the deep water corals lives in that locality at the depth to which the boring went. This finding supports subsidence theory.

(ii) *Cary* (1931) made 3 boring at different distances from the shore into a reef a Samoa (Pacific island) and concluded that the reef rested on a level platform cut by the action of waves. This supports the glacial control theory.

(iii) The Great Barrier Reef Committee made two boring, one in 1928 and the other in 1938 on the Great Barrier Reef. Both borning gave the same result that the coral material extended out only to 400 to 450 feet and below this there was nothing but shore sand containing shells of various animals. There was no evidence of any underlying platform. Therefore this finding also supports Darwin's subsidence theory. Thus Darwin's subsidence theory applies of many reefs but some reefs may have been laid down on pre-existing platforms.

Some important facts about reefs

Tropical storms can modify the reefs very much. Quarrying can also damage reefs as in India, where in 1971 *Pillai* has estimated that nearly 250 cubic meters of reefs material are removed per day for use in the production of cement, calcium carbide, calcium carbonate etc. Recently much concern has been expressed for the safety of some oceanic islands and their reef food chains because some reefs are being destroyed by ever increasing population of the Crown-of-thorns starfish.

Acanthaster planei. These starfishes feed upon the living coral and have caused much reef destruction in some parts.

Economic importance of coral reefs

The coral reefs are of much importance to oil industry. They form highly favourable sites for the accumulation of petroleum deposits.

The coral reefs are of importance for *curio trade.* Many plant and animals like sponges, molluscs, fishes, echinoderms etc. grow on these reefs. Even some humans inhabit them.

Some corals form highly priced decorative pieces.

Corellium rubrem is considered a precious stone. The red coral and organ pipe coral are used in medicine in South India. Skeleton of a few corals are used as building material.

Coral skeletons are also used in the formation of time, mortar and cement. The skeletons are also used in making ridges which act as natural barriers against sea erosion and cyclonic storms.

The coral reefs serve as good nursery grounds for commercially important fishes. They form more colourful and beautiful fishes.

29

POLYMORPHISM

Amongst the coelenterates, hydrozoans provide very good examples of polymorphism. The phenomenon is essentially for division of labour. Division of labour is first seen in the cells of *Hydra* where the cells are specialized to perform different functions of individual as a whole. Physiological differentiation of this type had its effect upon the morphology of cells which led to cell specialization and give rise to cells of different structures. In *Obelia* this specialization is carried still further. In it not only cells are specialised but individuals get specialised to perform different functions. The polyp perform different functions. The polyp performs vegetative function such as feeding, respiration, etc. and the free swimming medusae are reproductive in nature.

There are different types of polypoids and medusoids specialized for different functions. There are three types of polypoid and four types of medusoids individuals as given below:

I. POLYPOID ZOOIDS

1. **Gastrozooids.** The gastrozooids or the siphons are the nutritive or food-ingesting individuals of the colony. Each gastrozooid is a tubular or saccular structure with a large mouth. A single, long, contractile and hollow tentacle arises from the base of the gastrozooid. It bears numerous lateral contractile branches called the *tentilla*, each ending into a knob or coil of nematocysts.
2. **Dactylozooids.** These are the protective polyps of the colony and are variously known as *palpons*, *tasters* or *feelers*. Typically they resemble the gastrozooids except that they lack a mouth and their basal tentacle is unbranched. In *Vellela* and *Porpita* the dactylozo oids arise from the margin of the colony in the form of long, hollow and tentacle-like fringing bodies called the *tentaculozooids*. When associated with gonophores, the tentacle-like dactylozooids are known as *gonopalpoons*. In *Physalia* the dactylozooids become excessively long.
3. **Gonozooids.** They are reproductive zooids which are also known as *blastostyles*. They are without mouth and tentacle. They reproduce asexually by budding and form medusae. In *Vellela* and *Porpita*, they resemble a gastrozooid and possess a mouth. Usually, the gonozooids take the form of branched stalks, called the *gonodendra*. These bear grape-like clusters of gonophores and are often provided with gonopalpons as in *Physalia*.

II. MEDUSOID ZOOIDS

1. **Swimming bell.** The swimming bells which are also known as *nectocalyces, nectophores* or *nectozooids* are medusoid form with a bell, velum, four radial canals and a ring canal. But these are devoid of mouth, manubrium, tentacles and sense organs. Its shape is variable and may be bilaterally symmetrical, prismatic, elongated or flatenned. Due to well developed musculature, swimming bells act as excellent swimming organs and help in the locomotion of the colony.
2. **Pneumatophores.** The pneumatophores or the *floats* are bladder or vesicle-like structures filled with gas, and keep the colony floating. Each pneumatophore represents an inverted medusa bell, devoid of mesogloea and consisting of an external exumbrellar wall, *pneumatocodon*, and an internal subumbrellar wall, the *pneumatosaccus* or *air-sac*. The walls of

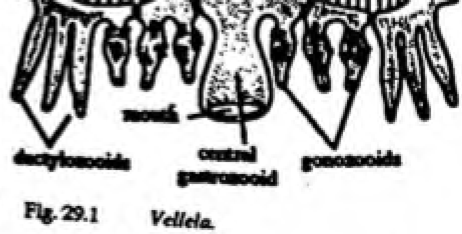


Fig. 29.1 *Vellela.*

both these are double-layered and are highly muscular. The space between the two walls is known as *gastrovascular cavity.*

A great degree of variation in shape and size is observed in different siphonophores. In *Agalma*, the float is simple and its air sac is lined by a layer of chitin secreted by the epidermis.

The shape of pnematophone is variable and may or may not be divided into a number of concentric chitinous chambers arranged in one plane. These communicate with each other and with the central chambers by pores in their walls. The air sac may open or closed. The air sac may be perforated by a single or several pores. In some cases a portion of the float is partly constricted off and assumes the form of an ovoid medusa-like, called *aurophore.*

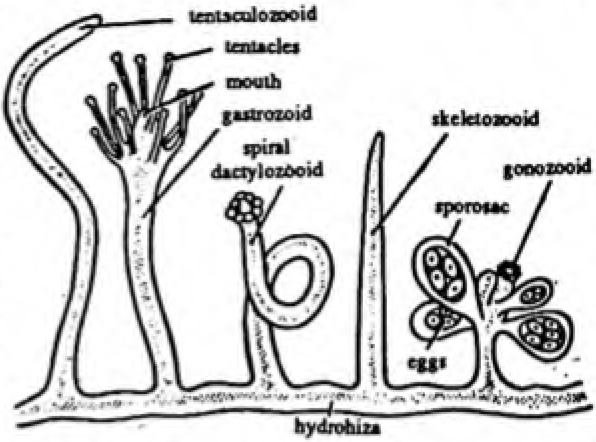


Fig. 29.2 *Hydractinia.*

3. **Bracts.** The bracts which are also known as the *phyllozooids* or *hydrophyllia* are thick, gelatinous and curved plates of mesogloea. These may be prism-like, leaf-like, shield-like or hemlet-like in appearance. They are unlike medusae and contain a simple or branched gastrovascular canal.

4. **Gonophores.** The gonophores or the reproductive medusoids occur singly on separate stalks or in clusters on polypoid gonozooids as in *Vellela* or on simple or branched gonodendra. The gonophores may be medusa-like with bell, velum, radial canals and a manubrium bearing gonads. But the mouth, tentacles and sense organs are always absent. In a number of hydrozoans e.g. *Physalia*, the female gonophores are medusa-like while the male ones are sac-like. In animals like *Physalia* (male), the gonophores may remain attached to the colony or are set free as in female *Physalia, Porpita* and *Vellela.* Since they cannot feed, they perish after the discharge of sex-cells. The gonophores are unisexual but the colonies are hermaphrodite bearing both types of gonophores in the same or separate clusters. Gonophores may be budded off from the pedical of the gastrozooid as in *Diphyes*, or from a blastostyle as in *Vellela* from coenosarc as in *Agalmopsis.*

GRADES

Some coelenterates posses only two types of zooids, others have three types and still others several types. These forms are respectively described as dimorphic, trimorphic and polymorphic. There are, thus, three grades of polymorphisms:

1. **Dimorphic Forms.** The dimorphic forms have two types of individuals, namely, *polyps* or *hydranths* and *medusae*. These types are regarded as the fundamental types from which the additional types found in the trimorphic and polymorphic colonies are derived by modification.

(a) ***Polyps.*** The polyps have a cylindrical form, are fixed by aboral end, enclose a wide gastrovascular cavity, and bear mouth and tentacles at the free oral end. They serve to feed the colony and are, therefore, also known as the *gastrozooids* or *trophozooids.*

(b) ***Medusae.*** The medusae have a bell-, bowl- or saucer-shaped body, lead free-swimming life when mature, enclose gastrovascular cavity in the form of narrow radial and circular canals, and bear mouth and marginal tentacles. They bear gonads and bring about sexual reproduction. They are, therefore, also known as the *gonophores* or *sexual zooids.*

Though diverse in form and function, the polyps and medusae have a similar basic plan so much so that they can be derived from each other.

Bougainvillea. (Class Hydrozoa) and *Corallium* (class Actinozoa) are examples of dimorphic colonies.

(a) *Bougainvillea.* The polyps are stalked and uncovered, have an elongated manubrium and bear a single circled of solid filiform tentacles. Medusae have four per-radial tufts of simple marginal tentacles and four groups of branched oral tentacles. They arise by budding from the hydrocaulus, polyp stalk and other medusae.

(b) *Corallium.* The zooids of *Corallium* are called *autozooids* and *siphonozooids.* Both are polypoid. The autozooids have tentacles and four groups of branched oral tentacles well developed mesenteries and a normal siphonoglyph. They serve to feed

coloney. The siphonozooids are small, lack tentacles, have reduced mesenteries and very large siphonoglyph. They serve to drive a current of water through the cavities of the colony and bear gonad.

2. **Trimorphic Forms.** The trimorphic forms have three types of zooids, i.e. *polyps, medusae* and *gonozooids* or *dactylozooids*. The polyps and medusae are similar to those of dimorphic forms. The gonozooids are modified polyps. They lack mouth and tentacles. They serve to bud off medusae or their morphological equivalents. The dactylozooids are also modified polyps. They are mouthless and serve to protect the colony.

   Examples of trimorphic colonies are many. *Obelia* and *Millepora* are well known.

(a) *Obelia.* The zooids of *Obelia* include polyps, gonozooids and medusae. The polyps are surrounded by hydrothecae and gonozooids by gonothecae. The medusae are saucer-like and bear gonads on radial canals.

(b) *Millepora.* The zooids of *Millepora* include gastrozooids, dactylozooids and medusae. The gastrozooids have short plump body with mouth and four knob-like tentacles. The dactylozooids have a long, slender body without mouth but with several, short, alternating, knobbed tentacles. The medusae develop in pits or ampullae of the colony and are greatly reduced, being without velum, mouth, tentacles and canals. They bear four nematocyst-bearing knobs on the margin and gonads on the long manubrium.

3. **Polymorphic Forms.** The polymorphic forms have several types of zooids. All these are modifications of the polyps and medusae. The best known polymorphic forms are *Hydractinia* and members of the order *Sinphonophora*

(a) *Hydractinia. Hydractinia* develops four types of zooids: *gastrozooids, dactylozooids, gonozooids* and *sporosacs*. The gastrolozooids have mouth and tentacles and feed the colony. The dactylozooids lack mouth and are defensive in function. They are further of two types: *spiral zooids* with short capitate tentacles and *tentaculozooids* which are long, slender and devoid of tentacles. The gonozooids retain short tentacles called the *nematocyst heads*. The sporosacs are reduced sac-like medusae. They produce gametes, either ova or sperms.

(b) *Siphonophora.* The siphonophores form free-swimming colonies with the highest degree of polymorphism. Their polyps occur in three modifications: gastrozooids, dactylozooids and gonozooids.

   (i) *Gastrozooids.* The gastrozooids are also called the siphonozooids, hence the name of the order. They feed the colony. They have the usual polyp form but lack the usually located tentacular ring. Instead, they bear a single, hollow, long and contractile tentacle at or near the base. The tentacle gives off lateral branches; the *tentilla*, each ending in a knob or coil of nematocysts.

   (ii) *Dactylozooids.* The dactylozooids are also called the *palpons, feelers* or *tasters*. They lack mouth and their basal tentacle is unbranched. They may be long, hollow and tentacle-like, when they are termed the *tentaculozooids.*

   (iii) *Gonozooids.* The gonozooids may look like the gastrozooids and even have a mouth, but lack a tentacle. Usually, however, they are long, slender and branched and are called *gonodendra.* They may bear tentacle-like dactylozooids called the *gonopalpons.* The gonozooids produce clusters of gonophores on them.

   The medusoid individuals exist in four modifications: swimming bells, bracts, gonophores and pneumatophores.

   (i) *Swimming Bells.* These are also termed the *nectophores* or *nectocalyces.* They are medusae with velum and radial and circular canals, but without mouth, manubrium, gonads and sense organs. They are very muscular and bring about locomotion of the colony.

   (ii) *Bracts.* These are also called the *hydrophyllia* or *phyllozooids.* They are thick, gelatinous individuals with simple or branched gastrovascular cavity. They are protective in function.

   (iii) *Gonophores.* The gonophores may be medusa-like but lack mouth, tentacles and sense organs. They may be reduced to rounded sacs. In some cases, the female gonophores are medusa-like and male gonophores are sac like. The gonophores produce gametes.

   (iv) *Pneumatophore.* It is also known as the *float.* It is an inverted medusa without mesogloea. Its outer (exumbrellar) and inner (subumbrellar) walls are respectively called the *pneumatocodon* and *pneumatosaccus* or *air-sac.* The opening of the air-sac directed upwards, is reduced to a small pore, the *pneumatopore,* and is guarded by a sphincter muscle. At the bottom (original roof) of the air-sac, the epidermis is modified into a *gas gland* that secretes gas having composition

similar to that of air. The float keeps the colony affloat.

All types of zooids arise by budding from a common *stem* or *coenosarc*. The latter may have the form of a tube or a disc and bears zooids in groups called *cormidia*.

The common polymorphic siphonophores are *Halistemma*, *Physalia*, *Velella* and *Porpita*.

(a) *Halistemma*. *Halistemma* posses a long slender stem with a small float at the top, several closet set swimming bells below the float and numerous cormidia lower down. The cormidia arise from nodes and each comprises a gastrozooid or dactylozooid and several sporosacs. Bracts arise from the internodes and partly cover the sporosacs.

(b) *Physalia*. *Physalia* has a disc-like coenosarc with a large sail-bearing, baloon-like float over it and several cormidia hanging from it. A cormidium consists or gastrozooids, small and large dactylozooids, gonodendra bearing gonophores, gonopalpoons and peculiar gelatinous zooids of unknown function. The colony is poisonous.

(c) *Velella*. *Velella* has a rhomboidal float divided internally into a number of gas filled chambers. It bears an oblique sail above and a disk-like coenosarc beneath. There is a single, large, central gastrozooid surrounded by gonozooids which are, in turn, surrounded by dactylozooids. The gastrozooids lack a tentacle. The gonozooids have mouth and bear gonophores at the base. Dactylozooids are tentacles-like.

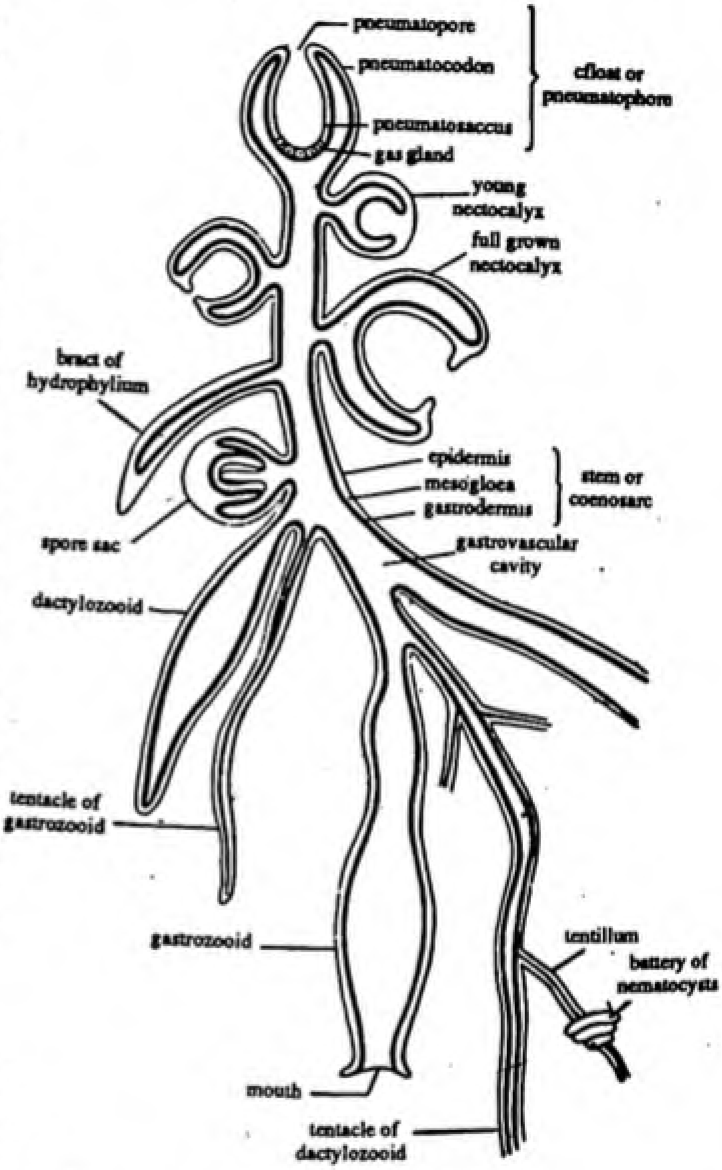


Fig. 29.3 Diagrammatic V.S. of a *siphonophore*.

ORIGIN OF POLYMORPHISM

After studying the polymorphism in coelenterates, the question arises whether the metagenesis is a direct consequence of polymorphism or the life-cycle of primitive coelenterate has led to polymorphism. According to one view, the original coelenterate was a polyp and through specialization the sexual function was relegated to the secondarily developed medusoid form and this led to metagenesis. According to another view, the ancestral coelenterate was a medusoid form and the polypoid generation is persistent larval form, thus leading to polymorphism.

(1) **Polyp Origin Theory.** This theory was proposed by *Huxley, Eschscholtz* and *Metshnikoff.* According to this theory component zooids, are really organs of a single medusoid individual, whose manubrium, tentacles and umbrella have become multiplied and migrated from their primitive positions. According to this theory, the various zooids are organs that have not yet attained the grade of polymorphic individuals, so that siphonophores are the most primitive existing coelenterates. In short, a siphonophore, in possessing a marked degree of power of vegetative increase of its parts, resembles a plant more than an animal. The theory errs too much in denying the colonial nature of siphonophores.

(2) **Polyp Person Theory.** This theory was proposed by *Leuckart, Vogt* and *Gagenbaur*. According to this theory siphonophores are free-swimming polymorphic colonies of highly specialized polyps with the power to produce medusae. This theory maintains that the parts of a siphonophore are either polyps or medusae or both, but the primitive zooid of the colony is of the polyp type.

(3) **Sedgwick, Haeckel and Balfour.** These three hold the view that the colonial theory (polyp-person theory) is more appropriate but that the primitive zooid of the colony was a medusa which has produced other medusa by budding and that the parts of these possess the power of becoming discrete. Then they are removed from the bud to which they belong and in some cases, multiply secondarily. The many organisms of the colony, which according to the old colonial theory are modified polyps are, according to this view, nothing more than the parts of the medusiform individuals which have shifted their attachment and are therefore real organs. For instance the structures called palpons are to be looked upon as mouthless manubria of medusoid; the tentacles are to be looked upon as only surviving amongst the marginal tentacle of the medusoid. The theory agrees in asserting the colonial nature of Siphonophora but admits that there has been a vegetative repetition and specialization of certain organs which is demanded by the old colonial theory.

(4) **Moser's Theory.** Recently, *Moser* has revived the polyp-organs theory of *Huxley* and *Metshnikoff*. According to *Moser*, the various individuals of siphonophore colony are organs that have not yet attained the grade of polymorphic individuals; and, therefore, the siphonophores are the most primitive existing coelenterates. Although the theory has not gained general recognition, yet it cannot be doubted that the siphonophores early diverged form the coelenterate stem.

We may, therefore, conclude that the identification of the component structures (especially in the siphonophores) as organs or individuals is a problem which rather defies an easy solution and may best be left as such.

Polymorphism and Alternation of Generations

Polymorphism is intimately associated with the life-history of organisms. In monomorphic forms as in *Hydra*, the life-cycle is simple and without any larval stage. It may be represented by the formula *polyp-egg-polyp*. With the advent of polymorphism, the reproductive power of the organisms are divided among the different individuals of the colony. In these organisms the polyps reproduce asexually to form medusoid form, the *gonophore*, and the gonophore reproduces sexually to form the *polyp*. The life-cycle of such organisms may be represented by the formula: *medusa-egg-planula-polyp*. Thus the *alternation of generations* or *metagenesis* comes into existence in the life-cycle-the asexual polypoid generation alternates with the sexual medusoid generation.

30

HELMINTHES

Helminthes constitute a large assemblage of 'worms' of comparatively simple and varied organization. Helminthes is derived from Greek word *helmins* means 'worms'. The term worms is not correct because it is applied to elongated invertebrates without appendages and with bilateral symmetry. In 18th century all the worm-like animals were included in an old phylum-*Vermes* (*Linnaeus*, 1735). But this was a very heterogenous group which included a highly diverse assemblage of forms. In the modern classification this group is divided into several independent phyla such as Platyhelminthes, Aschelminthes, Annelida etc.

The term helminthes is restricted to a few phyla of invertebrate animals, all of which are superficially worm-like but they differ markedly in their morphology, life-history and bionomics. The helminthes are restricted to two phyla of Animal Kingdom. These are:

1. Platyhelminthes or flat-worms
2. Aschelminthes or round-worms

PHYLUM - PLATYHELMINTHES

Term *Plathelminthes* was proposed by *Gegenbaur* in 1859, means flatworms which refers to their characteristic contour of flatenned body. The term is derived from two Greek words - *platys* = flat; *helminthes* = worms. The animals show low organisation as they are without anus, skeletal, respiratory and circulatory systems. The body is filled with mesenchymal cells which are mesodermal in origin.

GENERAL CHARACTERS

1. Bilateral symmetrical body, with dorso-ventral flattening.
2. Body generally shows anterior cephalization that is deferentiation of anterior region into head.
3. Body generally worm like either long flat ribbon shapped or leaf-like. The outline of body bizaree shape in trematodes and segmented tape-like body in cestodes.
4. Most of the flat worms are of small to moderate dimensions to size varies from microscopic to the extreme elongation as much as 10 to 15 mm.
5. General colour creamy white but on account of the presence of food the body may acquire colour. Some of the free-living flat worms are brilliantly coloured, often brown, black or gray.
6. Body with various types of attachment in the form of adhesive secretions, suckers and hooks.
7. Body consists of three embryonic layer viz. ectoderm, mesoderm and endoderm.
8. In parasitic forms, the body is covered with a thick cuticle but free-living Turbellarians are clothed with cellular or syncytial epidermis.
9. The exo- and endoskeleton are completely absent therefore the body is generally soft with hooks, spines, spicules and thorns.
10. Body space is filled with a mesenchyma that is parenchymatous tissue, therefore, flat worms are acoelomate that is without coelom.

11. The digestive system is generally absent in tapeworms and acoela. But in other consists of mouth, pharynx and variously modified intestine.
12. Respiratory and circulatory systems are absent but some of the trematodes have system of tubes the so called lymphatic system of uncertain function.
13. The nervous system is of primitive type with missing of nervous tissue as brain in anterior-most region with several longitudinal ganglionated cord. Numerous transverse connections occur between the longitudinal cords. So the nervous system is generally ladder type.
14. Parasitic forms are without sensory organs but free-living forms are provided with sensory organs in the form of chemo-and tango-receptors, ciliated pits, statocysts and ocelli or eyes.
15. Excretory system well developed with proto-nephridial tubules with flame bulbs or cells. But accoela are without protonephridia.
16. Hermaphrodite rarely with separate sex. The eggs are generally devoid of yolk but with yolk cells. Varieties of copulatory organs are present. Cross-fertilization and self-fertilization both are common.
17. Development direct i.e. without larval stage or indirect with larval stages. Life cycles complicated with succession of larval stages involving one to three intermediate hosts.
18. Asexual reproduction common among fresh water forms.
19. Parthenogenesis and polyembryony common among trematodes and cestodes.
20. Endogenous and exogenous budding common in tapeworms.

Phylum platyhelminthes is divided into three classes. The classification followed here is from *Hyman* (1951).

I Class - Turbellaria

II Class - Trematoda

III Class - Cestoda

I CLASS - TURBELLARIA

Turbellaria is derived from Latin word '*turbella*' means a *stirring*. The animal produce turbulance in water by body cilia. They posses following characters:

1. The members of this class are broad, flat and leaf-like in shape.
2. They lead a free living life in fresh or salt water, in moist soil, some members may be commensal or parasite.
3. Body unsegmented, dorso-ventrally flatenned and covered with cilia.
4. The anterior end is differentiated into head.
5. Epidermis cellular or syncytial contains rod-like structures called *rhabdites*. The rhabdites are curved structure capable of discharging a chemical secretion.
6. Epidermis and mesenchyma are provided with unicellular glands of two types (a) cyanophilous which secrete adhesive secretion and (b) eosinophilous.
7. Turbellarians are abundently provided with adhesive organs which are of two types (a) glandulo - epidermal adhesive organs and (b) glandulo - muscular adhesive organs.
8. Alimentary canal incomplete i.e. with single opening, the mouth. Mouth is mid-ventral, sometimes near the centre of body. Intestine is blind or absent.
9. Excretory system with protonephridia.
10. Sense organs consist of tangoreceptors and chaemoreceptors.

11. Mostly bisexual or hermaphrodite or unisexual with very few exceptions.
12. Reproduction by asexual, sexual methods and by regeneration.
13. Cleavage spiral. Development direct without larval stage.

Classification of Turbellaria

The members of this class are found almost all places. It includes more than 1500 species. Class Turbellaria is divided into 5 orders.

1. Acoela
2. Rhabdocoela
3. Allocoela
4. Tricladida
5. Polycladida

Order 1 - Acoela (Gr. a = without, koilos = cavity)

1. They are minute, delicate turbellarians with a ventral mouth.
2. Mouth and pharynx are present. Pharynx simple when present but usually absent and so the intestine is also absent.
3. Parenchyma syncytial not differentiated into mesoderm and endoderm.
4. Protonephridia absent.
5. Food is taken in solid form and digested by endodermal cells.
6. Gonoducts, gonads and yolk glands are absent.
7. Exclusively marine forms living under stones, algae etc. at the sea bottom. Some live in the intestine of holothurians.

   Examples: *Convoluta*, *Hoplodiscus*.

Order 2 - Rhabdocoela (Gr. rhabdos = rod; koils = cavity)

1. Small tubellarian usually less than 3mm in length.
2. Mostly free-living, marine or fresh water.

   Some of them inhabit in the respiratory cavities of various fresh-water crustaceans, viz. *Temnocephala*.
3. Body is elongated, cylindrical or compressed with simple pharynx and simple unbranched sac-like intestine.
4. Yolk-glands may or may not be present.
5. Male with two to many testes, whereas the female with 1 to 2 ovaries.
6. Nervous system consists of two longitudinal nerve cords. Eyes are present in most of them.

   Order Rhabdocoela is divided into four sub-orders:

Sub-order (i) Notandropora

1. Exclusively fresh water forms.
2. Pharynx simple.
3. Single median protonephridium.

4. Single compact testis mass, penis unarmed.
5. Yolk-gland is absent.
6. Asexual fission with chains of zooids.

   Examples: *Catenula, Rhynchoscolex, Stenostomum.*

Sub-order (ii) Opisthandropora

1. Fresh water or marine forms.
2. Pharynx is simple.
3. Excretory system consists of paired protonephridia.
4. Compact testes, penis armed with a stylet.
5. Yolk glands absent.
6. Asexual reproduction with chains of zooids.

   Examples: *Microstomum, Macrostomum*

Sub-order (iii) Lecithophora

1. Fresh water, marine or terrestrial, commensel or parasitic.
2. Pharynx bulbose.
3. Protonephridia paired.
4. Separate ovaries and yolk glands.
5. Exclusively sexual reproduction.

   Examples: *Graffill, Anoplodium, Merostoma, Gyratrix.*

Sub-order (iv) Temnocephalida

1. Freshwater ectocommensal forms.
2. Anterior end having 2-12 tentacles.
3. Posterior end with 1 or 2 adhesive discs.
4. Pharynx doliform.
5. Gonopore simple.

   Examples: *Temnocephala, Monodiscus.*

Order 3 - Allocoela (Gr. allolos = different; koilos = cavity)

1. Mostly marine, few freshwater and brakish water forms. Some are ectoparisite or ectocommensal in habits.
2. The pharynx is bulb-like or plicate.
3. Intestine is straight or branched.
4. Excretory system consists of paired protonephridia with two or three branches and nephridiopores.
5. Nervous system with 3 or 4 pairs of longitudinal nerve cords provided with transverse commissures.
6. Reproductive system consists of numerous testes and a pair of ovaries. Penis papilla mostly present.

   Order Allocoela is divided into four Sub-orders.

Sub-order (i) Archiophora

1. Marine animals.
2. Pharynx plicate.
3. Female reproductive system primitive.
   Example: *Proporoplana*

Suborder (ii) Lecithoepitheliata

1. Marine, freshwater or terrestrial forms.
2. Pharynx simple or bulbose.
3. Penis with a cuticular stylet.
4. Female duct simple or none. Typical yolk glands absent, nutritive cells may surround the ova.
   Examples: *Hofstenia, Prorhynchus.*

Suborder (iii) Cumulata

1. Freshwater or marine forms.
2. Pharynx plicate or bulbose.
3. Intestine mostly without diverticulae.
4. Penis unarmed.
5. Separate ovaries and yolk glands or *germovitellaria.*
   Examples: *Hydrolimax, Plagiostomum.*

Suborder (iv) Seriata

1. Mostly marine and a few are freshwater forms.
2. Pharynx plicate.
3. Intestine with lateral diverticula.
4. Statocyst mainly present.
5. Ovaries and yolk glands are separate.
   Examples: *Monocelis, Otoplana.*

Order 4 Tricladida (Gr. treis = three; klados = branch)

1. Marine, freshwater or terrestrial forms.
2. Large turbellarians, measuring 2-60 cm in length.
3. Pharynx plicate usually backwardly directed.
4. Intestine three-branched sacs.
5. Eyespots usually present.
6. Two ovaries, 2 or numerous testes.
7. Female reproductive system provided with one or two copulatory bursa.
8. Penis with penis papilla, common genital aperture.

Order Tricladida is divided into three suborders.

Suborder (i) Maricola

1. Exlclusively marine forms.
2. A pair of eyes and auricular grooves.
3. Typical penis papilla sometimes armed with stylet.
4. Rounded copulatory bursa is generally present.
5. Only sexual reproduction.

   Examples: *Bdelloura, Ectoplana, Gunda.*

Suborder (ii) Paludicola

1. Mostly freshwater rarely brackish water forms.
2. Two to many eyes or eyeless.
3. Bursa with bursal canal, anterior to penis.
4. Reproduction mostly asexual.

   Examples: *Dugesia, Kenkia, Dendrocoelum.*

Suborder (iii) Terricole

1. Terrestrial tropical and subtropical forms.
2. Two or many eyes.
3. Bursa, if present, lies behind the penis.
4. Reproduction may be asexual.

   Examples: *Geoplana, Dolicoplana.*

Order 5 - Polycladida (Gr. poly = many; klados = branch)

1. Size modrate, from 2-20 mm. Dorsoventrally flat leaf-like body; they are exclusively marine.
2. Intestine with many branches.
3. Eyes and nerve cords are present.
4. There are numerous ovaries and testes.
5. Genital apertures separate.

   It includes two suborders:

Suborder (i) Acotylea

1. Pharynx usually vertical curtain like.
2. No suckers are present behind the female pore.
3. Tentacles nuchal type.
4. Eyes concentrated at anterior margin, not in pairs.

   Examples: *Sthylochus, Notoplana.*

Suborder (ii) Cotylea

1. Sucker present behind the female pore.
2. Pharynx tubular.
3. A pair of marginal tentacles bearing eyes or with a cluster of eyes in place of tentacles.

   Examples: *Thysamozoon, Yungia.*

CLASS II TREMATODA

1. They are ecto- or endoparasites and commonly called 'flukes'.
2. Body is usually unsegmented, dorso-ventrally flatened and leaf-like.
3. Size varies from 0.5 mm to 1 or several cm. long.
4. Body is covered by thick cuticle and no cilia.
5. Suckers and sometimes hooks are present. Oral sucker present at anterior end for feeding, ventral sucker for attachment.
6. Epidermis absent. Rhabdites are absent.
7. Digestive system consists of mouth, muscular pharynx and intestine usually with two main branches. Anus is absent.
8. In some cases there is a system of parenchymal vessels showing the presence of primitive circulatory system.
9. Excretory organs consists of protonephridia.
10. There are three pairs of longitudinal nerve cords. Sense organs are poorly developed.
11. Bisexual or hermaphrodite except blood fluke (*Schistosoma*).
12. Single ovary and many testes. Cross fertilization takes place. Development direct or indirect.
13. Life-cycle simple or complicated with more than one hosts.

    There are about 6000 species in class Trematoda. This class is divided into three orders:

    Order 1 - Monogenea

    Order 2 - Aspidobothria

    Order 3 - Digenea

Order 1 - Monogenea

1. They are ectoparasite mostly in cold-blooded animals (fishes).
2. The life-cycle is simple and passed in one host only, monogenetic.
3. Oral sucker absent, when present is poorly developed.
4. A pair of adhesive structures, the opisthaptor, is found on the posterior end.
5. A large disc-shaped structure, the *opisthaptor*, is found on the posterior end. It contains hooks and is lined with chitin.
6. Paired excrecory pores are present in the anterior part of the body.
7. Male and female genital pores are separate.
8. One or two vaginae are present. The uterus is small and contains few eggs.
9. Development is indirect through a larval stage called *onchomiracidium*.

   Order Monogenea is divided in two suborders:

Suborder (i) Monopisthocotylea

1. Opisthaptors are present without suckers but with books.
2. Genito-intestinal tract is absent.
3. Posterior adhesive organ is single or divided by septa.
4. Eye-spots usually present.

   Examples: *Gyrodactylus, Monocotyle, Heterocotyle, Amphibdella.*

Suborder (ii) Polyopisthocotylea

1. Opisthaptor contains many suckers and also books.
2. Oral suckers two, opening into oral cavity.
3. Genito-intestinal tract present.
4. Eye-spots are absent.

   Examples: *Polystomum, Diplozoon, Microcotyle.*

Order 2 - Aspidobothria

1. Endoparasite in the digestive tract of fishes and reptiles.
2. Oral sucker is absent.
3. The ventral sucker is divided by septa into many small parts. The books are absent in it.
4. Single excretory pore.
5. Only one testis is present.
6. Development direct, without alternation of hosts.

   Order Aspidobothria is divided into two families:

Family (a) Aspidogastridae

1. Sucker enormous circular, oval or elongated, divided by septa into one, three or four longitudinal rows of depressions termed *alveloli.*
2. Protonephridia have separate bladders and separate or a common nephridiopore situated near the posterior end.
3. Testis single.
4. Laurer's canal may be present.
5. Endoparasite in the mantle, pericardial and renal cavities of clams and snail and in digestive system of fish and turtle.

   Examples: *Aspidogaster, Cotylaspis, Cotylogaster.*

Family (b) Stichocotylidae

1. It consists of only one genus which lives in bile passage or spiral valve of fishes.
2. The life cycle is complex one, involving at least two hosts.

   Example: *Stichocotyle.*

Order 3 - Digenea

1. They are endoparasite in invertebrate and vertebrates.

2. Two to four hosts in the life-cycle.
3. Two suckers, without hooks, mouth within anterior sucker.
4. There is only one excretory pore present in the posterior region of the body.
5. There is a common gonopore for male and female reproductive systems. Vagina is absent.
6. Uterus is long branched with many eggs.
7. Their larval forms reproduce asexually before metamorphosis.

Order Digenea is divided into many families; some important ones are as:

Family (a) Bucephalidae

1. They are commonly called gastrostomes. The mouth is located in the middle of the body.
2. Anterior end bears a simple or lobate oral sucker or has a generally lobed hood-like extension.
3. Intestine sacciform.
4. Acetabulum absent.
5. Genital pore posterior.
6. The cercaria larvae known as oxhead, have a pair of long tails.
7. The primary host is fish and secondary host is clam.

Examples: *Bucephalus, Bucephalopsis.*

Family (b) Paramphistomidae

1. Body thick and fleshy with a powerful posterior sucker.
2. Cirrus pouch is present.
3. Oral sucker is absent.
4. Gonopore, situated in the anterior body half and provided with in some genera with a genital sucker.
5. Nephridiopore dorsal infront of acetabulum.
6. Uterus long having ascending limb. Vitelline glands follicular.
7. These are the endoparasites of gut and bile ducts.

Examples: *Paramphistomum, Gastrothylax*

Family (c) Opisthorchidae

1. These are distomes of small to large size.
2. They live in the bile passage of fish-eating reptiles, birds and mammals.
3. Body flat and semitransparent.
4. Excretory bladder 'V' shaped.
5. Testes posterior. Genital pore infront of acetabulum.

Examples: *Opisthorchis, Amphimerus, Metorchis.*

Family (d) Fasciolidae

1. Commonly known as liver flukes.

2. Body leaf-like and acetabulum near the oral sucker.
3. Gonopore just infront of the acetabulum.
4. Testes, ovary, vitelline glands all are branched.

   Examples: *Fasciola hepatica, Fasciplopsis buski*

Family (e) Echinostomatidae

1. Body slender, elongated with spiny or scaly cuticle.
2. Acetabulum large behind the oral sucker.
3. Collar of spines is present in cercarial and metacercarial stages.
4. It is commonly found in the intestine of birds.

   Examples: *Echinostoma, Echinoparyphium, Parochis, Himasthla.*

Family (f) Schistosomatidae

1. These are blood flukes that inhabil the hepatic portal system and pelvic veins of birds and mammals.
2. Sexes are separate.
3. Female lodges in a gynaecophoric canal of male.
4. Testes numerous and ovary tubular.

   Example: *Schistosoma*

Besides above families the others are:

Family - Zoognidae.	Examples: *Zoogonus, Nassa.*
Family - Allocreadidae.	Examples: *Bunodera, Plagioporus.*
Family - Azygiidae.	Examples: *Azygia, Otodistomum.*
Family - Hemiuridae.	Examples: *Halipegus, Derogenes.*
Family - Didymozoonidae.	Examples: *Dadymocystis.*
Family - Gorgoderidae.	Examples: *Gorgoderina, Gorgodera.*
Family - Plagiorchidae.	Examples: *Plagiorchis, Styphlodora.*
Family - Dicrocoelidae.	Examples: *Dicrocoelium, Eurytrema.*
Family - Heterophyidae.	Examples: *Stictodera, Heterophyes.*
Family - Microphallidae.	Examples: *Spelotrema, Maritrema.*
Family - Troglotrematidae.	Examples: *Paragonimus, Troglotrema.*
Family - Cyclocoelidae.	Examples: *Cyclocoelus, Typhlocoelum.*
Family - Clinostomatidae.	Example: *Clinostomum.*
Family - Notocotylidae.	Examples: *Notocotylus, Catatropis.*
Family - Strigeidae.	Examples: *Ophiosoma, Cyanthocotyle*
Family - Brachylaimidae.	Example: *Brachylaima.*
Family - Sanguinicolidae.	Example: *Sanguinicola.*
Family - Spirorchidae.	Examples: *Spirorchis, Hapalorhynchus*
Family - Heronimidae.	Example: *Heronimus.*

CLASS III CESTODA

. They are found as endoparasites in the intestine of vertebrates and are called tapeworms.

2. Body is flat, elongated and ribbon-like, measures from 1 mm to 10 metres in length.
3. Body is without epidermis, rhabdites, cilia but a cuticle is present.
4. Body is usually divided into a scolex or head, neck and few to many proglottids.
5. Scolex is provided with hooks or suckers or both.
6. Scolex is followed by neck which forms new 'proglottids' by transverse budding called strobilization.
7. Mouth and digestive tract are absent.
8. Excretory system consists of protonephridia with flame - cells.
9. Nervous system consists of ganglionated nerve ring in scolex and two pairs of lateral nerve cords in progiottids.
10. Each proglottid contains one or two sets of male and female reproductive organs. Thus they are hermaphrodite.
11. Several testes in the form of follicles and single-lobed ovary.
12. Uterus presents a great variety of structures.
13. Fertilization internal and self.
14. Life-cycle is complicated with hooked embryo, and is passed in more than one host.

Class Cestoda has about 3400 species. The class is divided into two sub-classes:

Sub-class (A) Cestodaria or Monozoa

Sub-class (B) Eucestoda or Merozoa

SUB-CLASS (A) CESTODARIA

1. Endoparasites in the intestine and coelomic cavities of fishes and reptiles.
2. Body is formed by one segment and without a scolex.
3. No alimentary canal.
4. Single set of reproductive organs.
5. Larva with ten hooks, known as pycophore.

Sub-class Cestodaria is divided into two orders.

Order 1 - Amphilinidea

1. They are endoparasites in the body cavity of ganoid fishes.
2. Frontal gland and protrusible pharynx are present in the anterior part of the body.
3. Suckers are absent.
4. A proboscis is present.
5. Male and female pores present in the posterior part of body.
6. Uterus is coiled and opens near the anterior end.

Example: *Amphilina*

Order 2 - Gyrocotylidea

1. They are endoparasites of chimaeroid fishes.
2. Anterior end has cup-like sucker.

3. Eversible proboscis at anterior end.
4. Male and female pores are situated at the anterior half of the body.
5. Uterus not coiled.

   Example: *Gyrocotylus.*

SUB-CLASS (B) EUCESTODA

1. Elongated, flat body is divided into many proglottids.
2. Body is divisible into scolex, neck and strobila.
3. Scolex with suckers, spines and hooks for attachment to host.
4. Each proglottid with male and female reproductive organs.
5. Larva with six hooks.

   Sub-class Eucestoda is divided into following orders.

Order 1 - Tetraphyllidea

1. Endoparasite, exclusively in the intestine of elasmobranch fishes.
2. Scolex provided with four bothria (sessile suckers) often with hooks.
3. Testes lie infront of ovaries.
4. Cirrus armed with hairs, spines or hooks.
5. Common genital atrium marginal.

   Examples: *Phyllobothrium, Acanthobothrium.*

Order 2 - Lecanicephaloidea

1. Intestinal parasites of elasmobranch fishes.
2. Scolex divided by a transverse groove in two parts upper with disc and lower with four suckers.
3. Vitellaria in two lateral bands.

   Examples: *Lecanicephalum, Polypocephalus.*

Order 3 - Proteocephalidea

1. These are endoparasites of freshwater fishes, amphibians and reptiles.
2. Scolex mobile with four lateral suckers, an apical sucker in some.
3. Ovary bilobed. Uterus with many branches and pores.
4. Vitellaria scattered.
5. Common genital atrium marginal.

   Examples: *Proteocephalus, Ophiotaenia*

Order 4 - Diphyllidea

1. Parasitic in the intestine of elasmobranch fishes.
2. Proglottids only 20 or less.
3. Scolex with two bothria and a spiny head stalk.

4. Vitellaria scattered.

   Example: *Echinobothrium.*

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Order 5 - Trypanorhyncha

1. Parasitic in the spiral valve of digestive tract of elasmobranch fishes.
2. Strobila is segmented and is of modrate size.
3. Scolex with two or four sessile bothria and four protrusible spiny proboscis.
4. Testes extend beyond ovary posteriorly.

   Examples: *Haplobothrium, Tetrarhynchus.*

Order 6 - Pseudophyllidea

1. Endoparasites in the intestine of fishes, birds and mammals.
2. The larva lives in crustaceans.
3. Generally six shallow groove-like suckers and hookless bothria are found on the scolex.
4. Proglottids may be absent or present.
5. Neck is not developed.
6. Many yolk glands are present.

   Examples: *Amphicotyle, Dibothriocephalus.*

Order 7 - Nippotaeniidea

1. Endoparasite in the intestine of Japanese freshwater fishes.
2. Scolex with single terminal sucker.
3. Proglottids few, each with one set of genitalia.
4. Vitellaria compect.

   Examples: *Nippotaenia, Amurotaenia.*

Order 8 - Taeniidea

1. Endoparasites in the intestine of birds and mammals.
2. Elongated body, with proglottids.
3. Scolex bears four suckers often with an apical rostellum armed with hooks.
4. Excretory system with four longitudinal vessels and flame cells.
5. Complete sets of reproductive organs in each proglottids. Single compact yolk gland.

   Examples: *Taenia, Echinococcus.*

Order 9 - Aporidea

1. It is endoparasite of swan (birds).
2. Scolex with four suckers, rostellum armed.
3. No segmentation, ootype, yolk glands and sex-ducts or pores.

   Examples: *Nematoparataenia, Gastrotaenia.*

POLYCHOERUS

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Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Acoela
Genus	-	*Polychoerus*

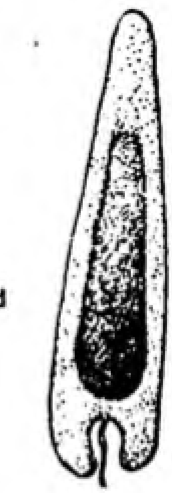

Fig. 30.1 *Polychoerus.*

1. It is found in littoral zone of ocean shores in colder winter.
2. It is bright orange or orange red in colour.
3. Body flat, oval, changeable shape. The anterior end is round while posterior end is not ched bearing tail filament.
4. Entire body is covered with cilia.
5. Statocyst is present in median line.
6. Digestive tract is absent.
7. Definite gonads are wanting. Yolk glands are absent. Definite oviduct absent.
8. The seminal bursa opens vertrally by female gonopore.
9. Penis is present.

CONVOLUTA

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Acoela
Genus	-	*Convoluta*

Fig. *Convoluta.*

1. *Convoluta* is found in sea water.
2. Living under stones, among algae and most commonly on the bottom mud.
3. Small worm with sides of the body are held curved ventrally without any projections.
4. But the body has pigment cells.
5. The anterior or cephalic end has two eyes, a statocyst and cluster of frontal glands.
6. The mouth is located near the anterior half of the ventral surface.
7. A digestive cavity is lacking.
8. The excretory system is completely absent.
9. Hermaphrodite but protandry is common.
10. The eggs are enclosed in a thin gelatinous capsule and are struck to some objects.
11. The eggs are developed directly into young worms that escape from the jelly.

CENTULA

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Rhabdocoela
Suborder	-	Notandropora

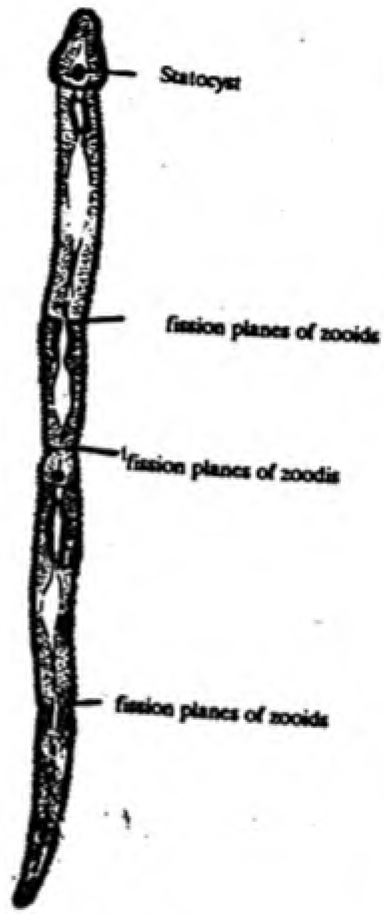

Fig. 30.3 *Centula.*

Genus *Centula*

1. It is a freshwater Turbellaria.
2. The pharynx is simple.
3. Single median protonephridium.
4. Nervous system consists of four pairs of longitudinal nerve cords and a statocyst.
5. Asexual reproduction by fission with chains of zooids.
6. No sexual reproduction.

MICROSTOMUM

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Rhabdocoela
Suborder	-	Opisthandropora
Genus	-	*Microstomum*

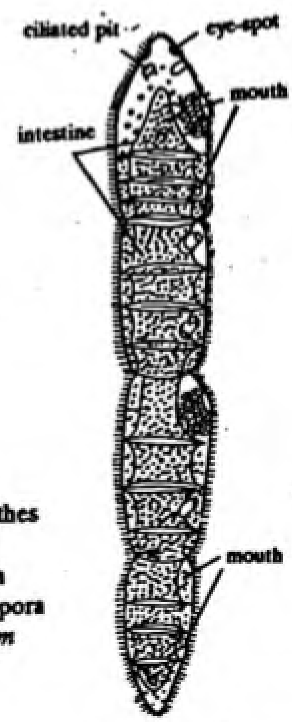

Fig. 30.4 *Microstomum.*

1. It is a microscopic, freshwater form.
2. It swims by means of cilia present on the body surface.

3. Its epidermis contains nematocysts derived from hydroid food.
4. It is found that *Microstomum* attack *Hydra* only when it needs nematocysts.
5. The digestive cavity is simple, unbranched and straight.
6. It reproduce asexually by repeated transverse fission forming a linear chain of 4, 8 or 16 zooids. Each zooid separates to become an individual.

TEMNOCEPHALA

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Rhabdocoela
Suborder	-	Temnocephalida
Genus	-	*Temnocephala*

1. It is found as an ecto- commensal on cray-fish, prawns and other crustaceans.
2. It contains 12 finger-like projections or *tentacles* at anterior end and an adhesive disc at the posterior end.
3. The border of syncytial epidermis is apparently cuticle devoid of cilia.
4. Mouth anterio-ventral. Pharynx thick walled and simple lobulated intestine present.
5. It feeds upon diatoms, rotifers and other small animals.
6. A pair of nephridiopores is present on the dorsal surface of the anterior part of the body.
7. Cerebral ganglion bears two dorsal eyes.
8. There are four testes and single ovary. Their gonoducts leading into a common genital atrium.

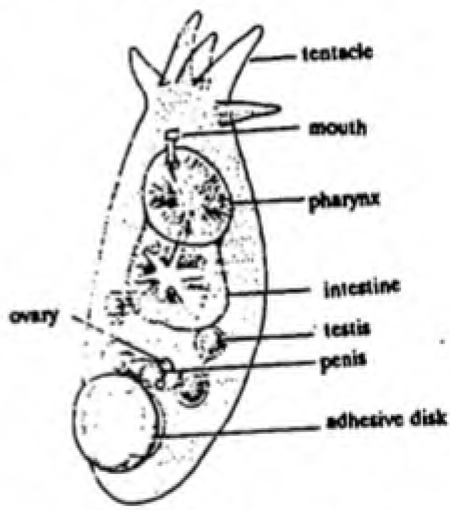

Fig. 30.5 *Temnocephala.*

PLAGIOSTOMUM

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Allocoela
Suborder	-	Cumulata
Genus	-	*Plagiostomum*

1. It is present in both fresh and marine waters.
2. Mouth is anterior.
3. Pharynx is bulbose. Intestine with short diverticula.
4. Gonopore posterior.
5. Sperm is characteristic in having wing-like lateral expansions.

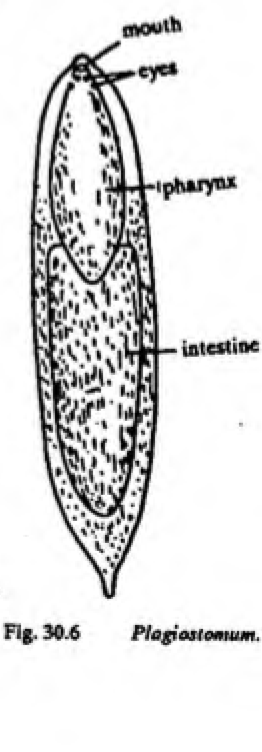

Fig. 30.6 *Plagiostomum.*

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BIPALIUM

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Tricladida
Suborder	-	Terricola
Genus	-	*Bipalium*

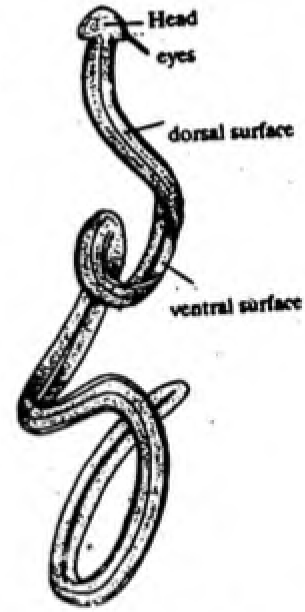

Fig. 30.7 *Bipalium.*

1. *Bipalium* is a long terrestrial turbellarian living the humid soil on the floor of tropical forests.
2. It is cosmopolitan in distribution.
3. The animal measures 20-50 cm in length.
4. It consists of an expanded lunate head and cylindrical long body.
5. Numerous eyes are present on the margin of the head and sides of body.
6. There are stripes on the dorsal surface and a creeping sole on the ventral surface.
7. The stripes are purple, black, yellow, olive and grey in colour.
8. Reproduction generally asexual. It never becomes sexual in temperate climate and it propogates by fragmentation.
9. *Bipalium adventium* breeds sexually.

GUNDA

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Tricladida
Suborder	-	Moricola
Genus	-	*Gunda (Procerodes)*

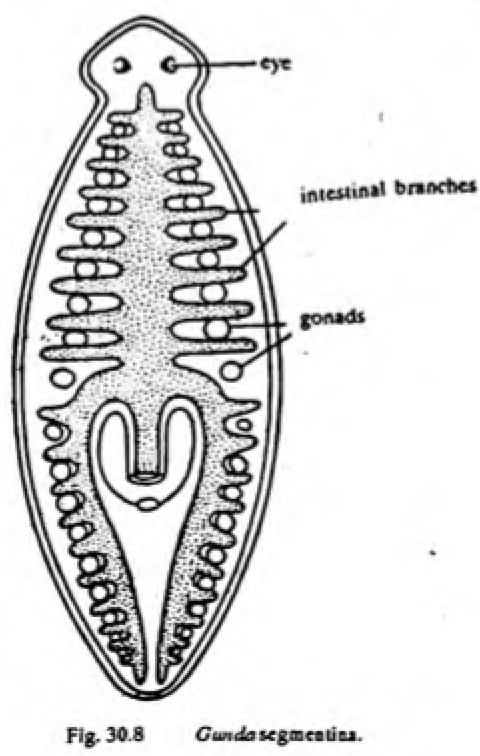

Fig. 30.8 *Gunda* segmentina.

1. It is a marine animal.
2. The auricle and a pair of eye or ocelli are present in the anterior end.
3. Intestine has regularly arranged intestinal diverticulae. The gonads alternate with the diverticulae giving the appearance of segmentation.
4. Incapable of sexual reproduction.
5. *Lang* used the feature of intestine as a classical example in support the gonocoel theory of coelom formation by *Haeckel*.

THYSANOZOON

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Polycladida
Suborder	-	Cotylea
Genus	-	*Thysanozoon*

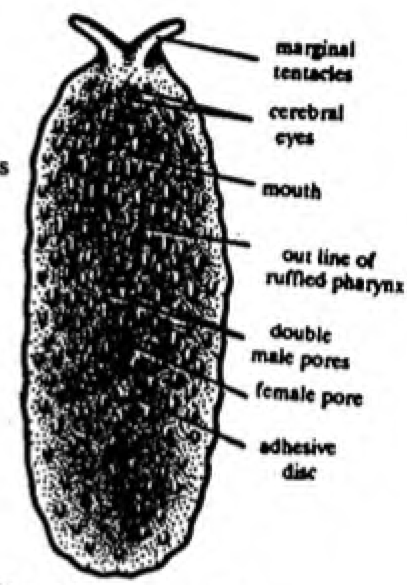

Fig. 30.9 *Thysanozoon.*

1. It is found in a less cold water of sea.
2. It has an oval body with dorsal surface beset with papillae, each receiving a branch from intestine.
3. Anterior end bears a pair of marginal tentacles and numerous cerebral eyes.
4. Pharynx is tubular.
5. Glandulo-muscular adhesive organ is present on the dorsal surface behind the female gonopores.
6. A single female genital pore lies behind the male genital pores.
7. Seminal bursa is absent.

APIDOGASTER

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Aspidobothria
Genus	-	*Apidogaster*

1. It is an endoparasite in the pericardial and renal cavities of freshwater mussel and in the gut of fishes and turtles.
2. Body is elongated and dorsoventrally flatenned with anterior narrow end.
3. The narrow anterior end has a subterminal mouth which is devoid of oral sucker
4. A large sucker appears which occupies great space in the posterior region of body. The sucker is sub-divided into four longitudinal rows of sucking cups or alveoli.
5. Gut is simple and straight.
6. Excretory system consists of protonephridia with excretory bladders.
7. Bisexual life-cycle without change of host.

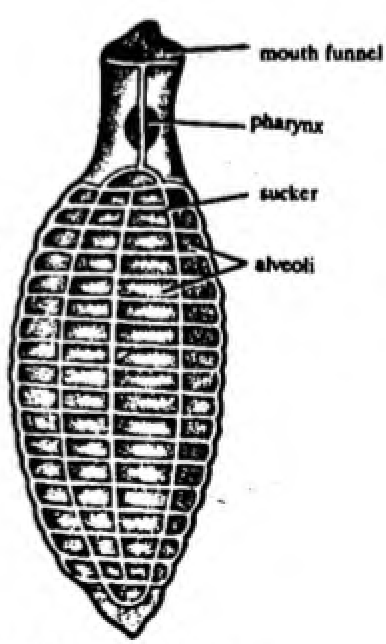

Fig. 30.10 *Aspidogaster.*

POLYSTOMUM

Phylum	-	Platyhelminthes
Class	-	~~Monogenea~~
Order	-	Monogenea
Suborder	-	Polyopisthocotylea
Genus	-	*Polystomum*

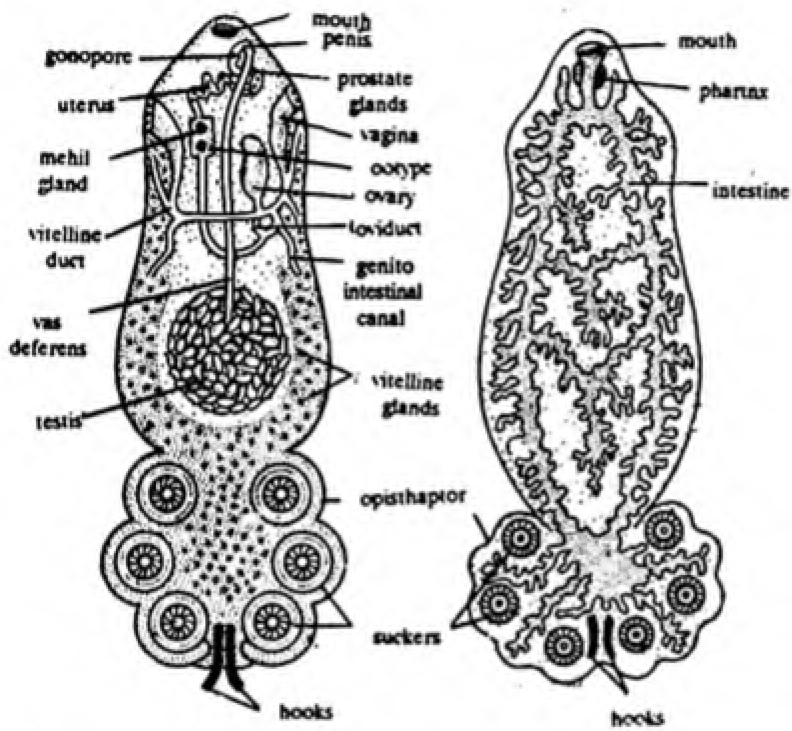

Fig. 30.11 *Polystomum.*

1. It is an endoparasite in the urinary bladdar of frogs, and turtles.
2. Body is leaf-like and dorso-ventally flattened.
3. The posterior region has a disc-shaped opisthaptor with six cup-like suckers and 2 to 4 large chitinous hooks.
4. Mouth is surrounded by a oral sucker.
5. Intestine is bifurcated.
6. Hermaphrodite with single ovary and numerous tests.
7. Breeding season starts in spring. Eggs are produced in the urinary bladder of frog and discharged into the water along with the urine of the host.
8. Hatching takes place after 4 to 5 weeks and larva attaches to the gills of tadpole and later develop into adult in the alimentary canal of metamorphosed tadpole.

DIPLOZOON

Phylum	Platyhelminthes
Class	~~Monogenea~~ -
Order	Monogenea

Suborder		Polyopisthocotylea
Genus		*Polystomum*

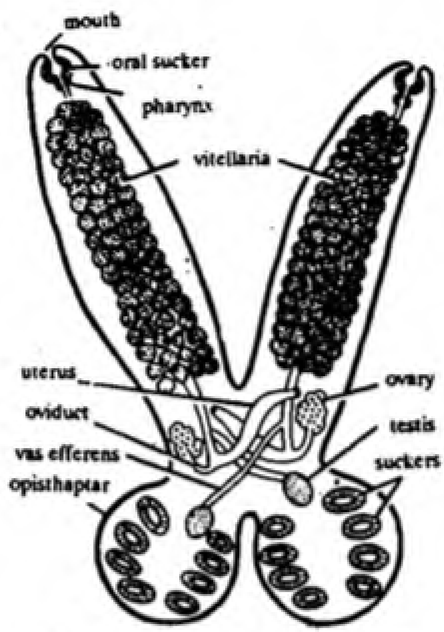

Fig. 30.12 *Diplozoon*. Two individuals.

1. *Diplozoon* is an ectoparasite, found attached to the gills of freshwater fishes, feeding on their blood.
2. Two individuals are always found attached permanently together in the form of 'X'.
3. Opisthaptor bears eight suckers arranged in two rows of four each.
4. Digestive system consists of mouth surrounded by oral sucker, pharynx and intestine. Intestine is not bifurcated.
5. Reproductive system consists of a testis and ovary along with their usual ducts.
6. The sperm duct, uterus and vagina of one individual cross with those or other and thus ensures cross fertilization. Uterus surrounded by mehlis' glands and contains one egg.
7. Egg differenciates into diporpa larva, two of which unite and metamorphosed into adult individual. Larva has two eyes digestive system & a pair of suckers.

GYRODACTYLUS

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Monogenea
Suborder	-	Monopisthocotylea
Genus	-	*Gyrodactylus*

1. It is an ectoparasite on the skin and gills of freshwater fishes.
2. Body is minute and elongate.
3. Anterior end is provided with adhesive glands and organs. Oral sucker is absent.
4. Eyes are absent.
5. Opisthaptor is disc or wedge-shaped and bears one pair of anchors and eight pairs of hooklets.

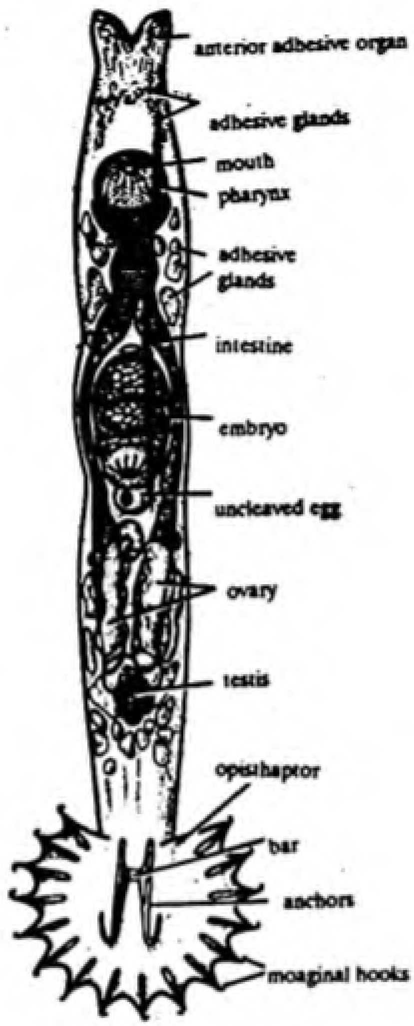

Fig. 30.13 *Gyodactylus.*

6. Intestine is sac-like forked into two branches without diverticula.
7. Genito-intestinal canal is absent. Genital pore is median.
8. Development is intra-uterine i.e. viviparous.
9. A remarkable feature is that a second embryo is produced within the first one, a third within the second and a fourth within the third. The first embryo, on completing its development passes out, still enclosing the other embyros, and attaches directly to a host fish.

GIGANTOCOTYLE (PARAMPHISTOMUM)

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Digenea
Family	-	Paramphistomidae
Genus	-	*Gigantocotyle*

1. It is an endoparasite in the rumen of cattles and bile-duct of sheep, goat etc.

2. Body is dorsoventrally flatenned and measuring 12-14 mm in length.
3. Mouth lies at the anterior end and without an oral sucker.
4. Acetabulum is very prominant and lies at the posterior end.
5. Digestive system consists of mouth, highly muscular pharynx and bifurcated, unbranched intestine.
6. Parenchyma has a sort of delicate tubes forming much branched lymph tic system.
7. Testes are lobed and occur near the middle of the body.
8. Ovary is small, lobed and lies posterior to testes.
9. Vitellaria are scattered on the sides of animal.
10. Genital pore is just behind the bifurcation of intestine.
11. Uterus is slightly folded and eggs are very large.

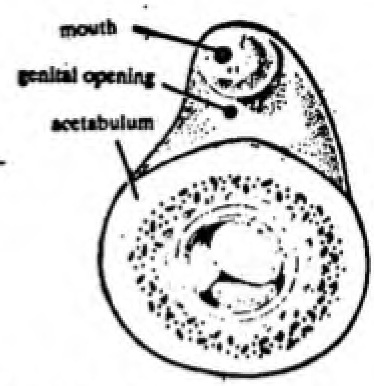

Fig. 30.14 *Gigantocotyle.*

GASTRODISCOIDES HOMINIS

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Digenea
Family	-	Paramphistomidae
Genus	-	*Gastrodiscoides*
Species	-	*hominis*

1. It is an endoparasite in the colon and caecum of man.
2. It is found in India and Indo-China.
3. It measures 5-7 mm in length.
4. Body is differentiated into anterior and posterior part.
5. Terminal mouth is present an anterior part.
6. Oral sucker is absent.
7. Posterior part bears a prominant acetabulum on ventral side.
8. Gonopore is in the anterior half of the body on ventral side.
9. Excretory pore lies on the dorsal side infront of acetabulum.
10. The secondary host is snail.
11. It causes inflammation and diarrhoea.

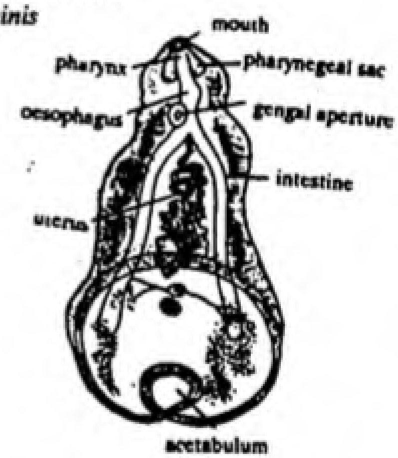

Fig. 30.15 *Gastrodiscoides.*

GASTROTHYLAX

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Digenea
Family	-	Paramphistomidae
Genus	-	*Gastrothylax*

1. It is an endoparasite in the rumen of cattles.
2. It is elongated animal possessing a deep ventral pouch which extends upton the ventral sucker and it is supposed to be

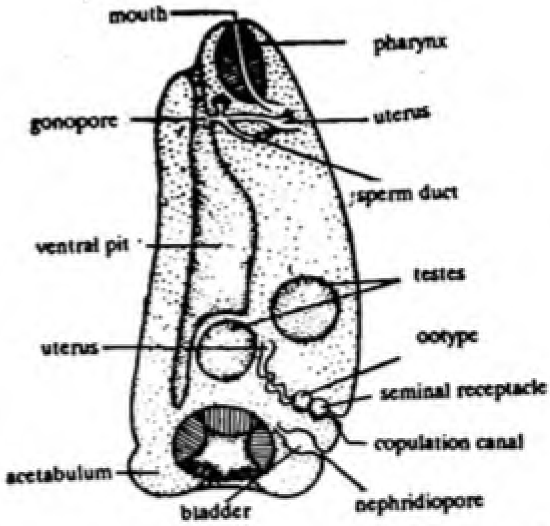

Fig. 30.16 *Gastrothylax.*

elongated genital chamber.

3. Digestive system includes mouth, pharynx, oesophegus and simple non-diverticulated intestine.
4. Two rounded testes near the base of the pouch.
5. Female reproductive organs consists of single ovary, uterus, ootype, vagina and seminal recepticle.
6. Single excretory pore is present.
7. Posterior end is divided with large acetabulum or adhesive sucker.

FASCIOLOPSIS BUSKI

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Digenea
Family	-	Fasciolidae
Genus	-	*Fasciolopsis*
Species	-	*buski*

1. It is a large intestinal fluke of man, dogs, pigs etc.
2. It is found in India and China.
3. It measures about 70 mm in length and 20 mm in width.
4. Oral sucker and acetabulum both are well developed.
5. Mouth surrounded by oral sucker leads into small pharynx. Oesophegus is short and leads into non-diverticulated caeca.
6. Gonads are present in posterior region of body.
7. Intermediate host is snail.
8. Cercaria larvae encyst on tubers of water caltrop or singhara. The singhara is eaten raw and thus infection occurs.

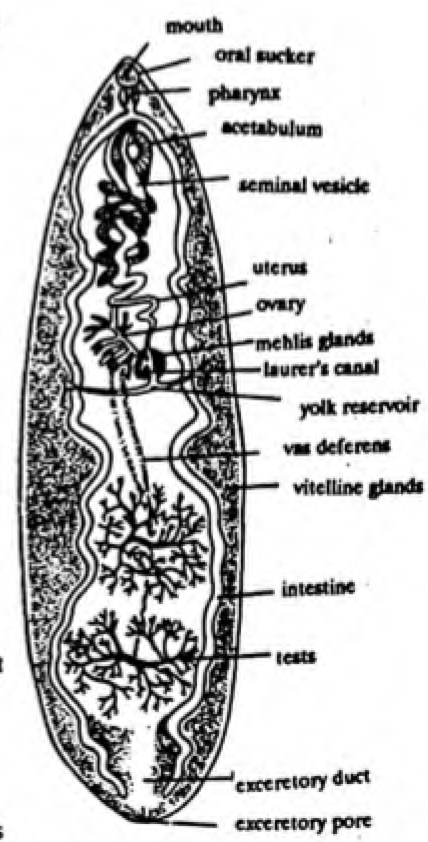

Fig. 30.17 *Fasciolopsis buski.*

9. It causes inflammation and haemorrhage of the intestine.

PARAGONIMUS WESTERMANNI

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Digenea
Genus	-	*Paragonimus*
Species	-	*westermanni*

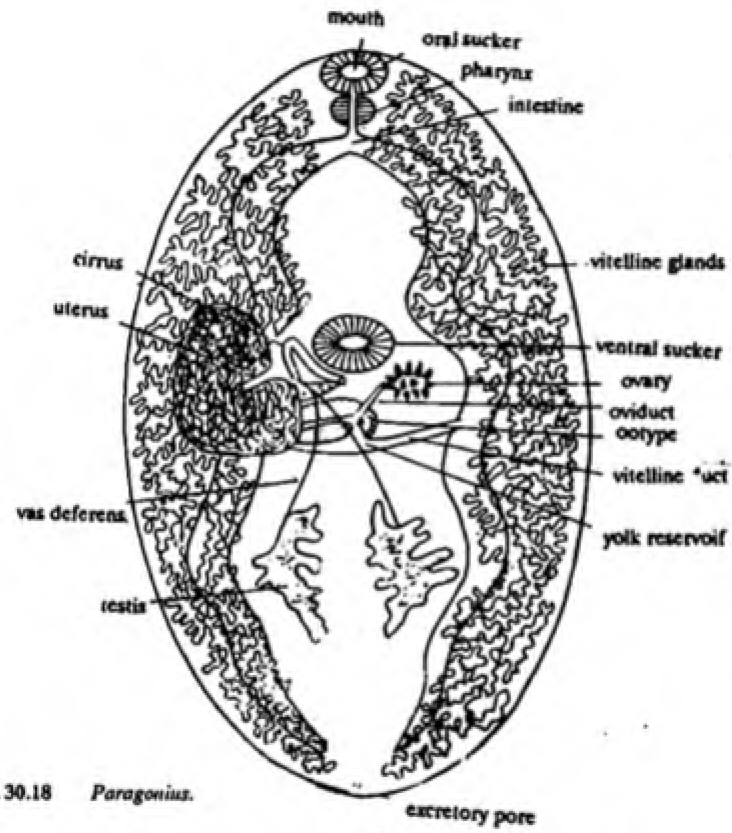

Fig. 30.18 *Paragonius.*

1. *Paragonimus westermanni* or Lung fluke is parasite in the lungs of mammal including man.
2. The body of the fluke is oval with well developed oral sucker surrounding the mouth and a ventral sucker in the centre of the body.
3. The internal organs are very much like that of *Fusciola hepatica.*
4. The cyst like pockets are formed around the parasite which rupture and liberate the eggs into bronchial tubes to be executed with sputum.
5. The miracidia live only few hours after hatching.
6. The cercariae are long, have small knob-like tail and spiny cuticle.
7. They do not swim but creep in leech-like manner.

8. They pierce the cuticle of cray-fish where they become encysted inside the tissues and gradually develop into mature infective metacercariae.
9. The infection of the new host usually takes place by eating infected crab or cray-fish
10. They cause or help in tuberculosis, cough and blood stained sputum.

AMPHILINA

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Cestodaria
Order	-	Amphilinida
Genus	-	*Amphilina*

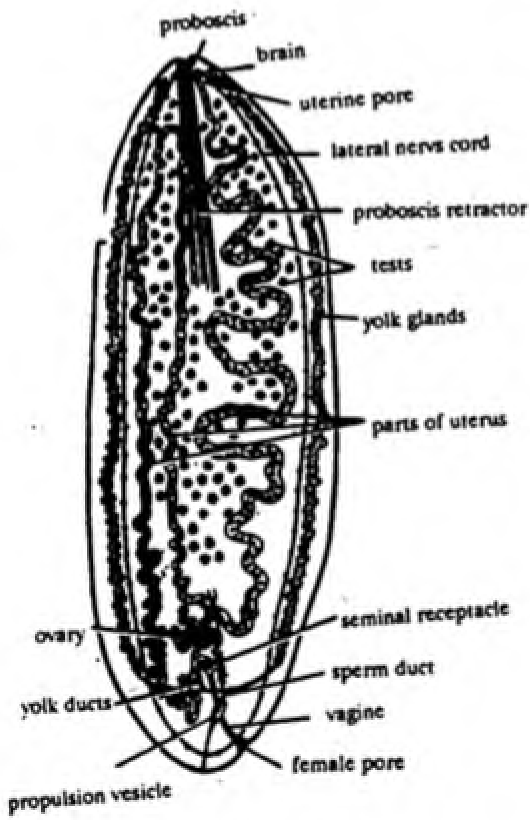

Fig. 30.19 *Amphilina.*

1. It is an endoparasite found in the coelom of fish, *Acipenser.*
2. Body flat and leaf-like. Scolex is absent.
3. Anterior end is provided with weakly developed protrusible proboscis.
4. Testes are scattered and cirrus is armed.
5. Vagina lies behind the ovary and opens on the left side. Uterus is coiled.
6. The intermediate host is a crustacean, *Gammarus,* which is eaten by *Acipenser.*

GYROCOTYLE

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Cestodaria
Order	-	Gyrocotylidea
Genus	-	*Gyrocotyle*

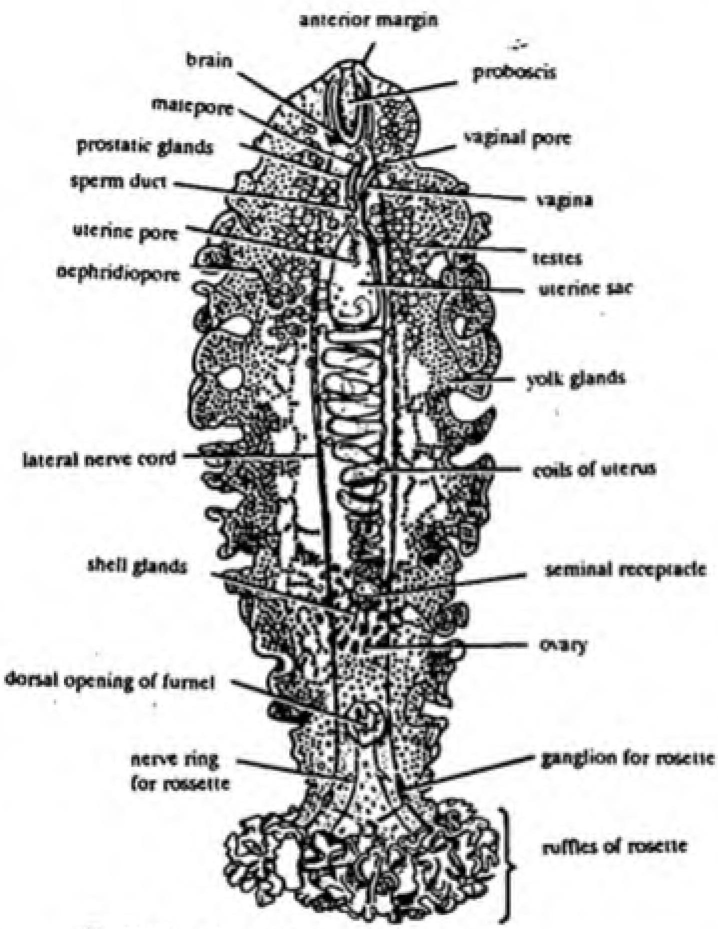

Fig. 30.20 *Gyrocotyle.*

1. These are endoparasite in the intestine of chimaeroid fishes.
2. Body is elongated and dorso-ventrally flatenned.
3. Anterior end bears a large opening that leads into a highly muscular protrusible mass, the *proboscis.*
4. Posterior end bears a rosette-shaped adhesive organ, surrounding a funnel shaped depression.
5. The margins of body are generally ruffled.
6. Bisexual. Male reproductive system comprises scattered testes, sperm duct and penis papilla. Female reproductive system comprises ovary, oviduct and uterus.
7. Follicles of yolk gland scattered throughout.

TETRARHYNCHUS

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Trypanorhyncha
Genus	-	*Tetrarhynchus*

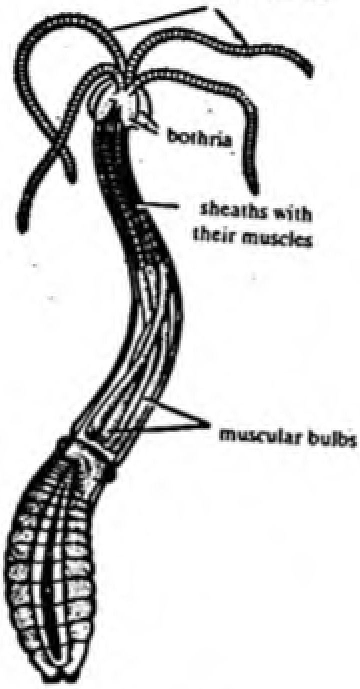

Fig. 30.21 *Tetrarhynchus.*

1. It is an endoparasite in the intestine of elasmobranch fishes.
2. Body is long divisible into scolex and proglottids.
3. Scolex is long and differentiated into a long proximal part containing the proboscis apparatus and a distal part bearing the bothria or sucker.
4. Scolex bears four suckers each with a eversible proboscis armed with spines. The proboscis are retractile in muscular sheaths which end in muscular bulbs.
5. Each proglottid contains a complete set of reproductive organs.

DIPHYLLOBOTHRIUM (DIBOTHRIOCEPHALUS)

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Pseudophyllidea
Genus	-	*Diphyllobothrium*
Species	-	*latum*

1. It is found in the intestine of man. It is world-wide in distribution.

2. It is the largest and most pathogenic cestod of human beings, measuring 20 metres in length.
3. Body is differentiated into scolex, neck and proglottids. The number of proglottids is 3000-4000.
4. Scolex is fusiform and bears two slit-like suckers or bothria.
5. Mature proglottid broader than long.
6. Each proglottid is hermaphrodite and contains complete sets of male and female reproductive organs.
7. Testes are numerous. Vasa efferentia unite to form coiled sperm duct.
8. Ovary is trilobed. Vagina runs posteriorly forming seminal vesicle. Uterus very much twisted.

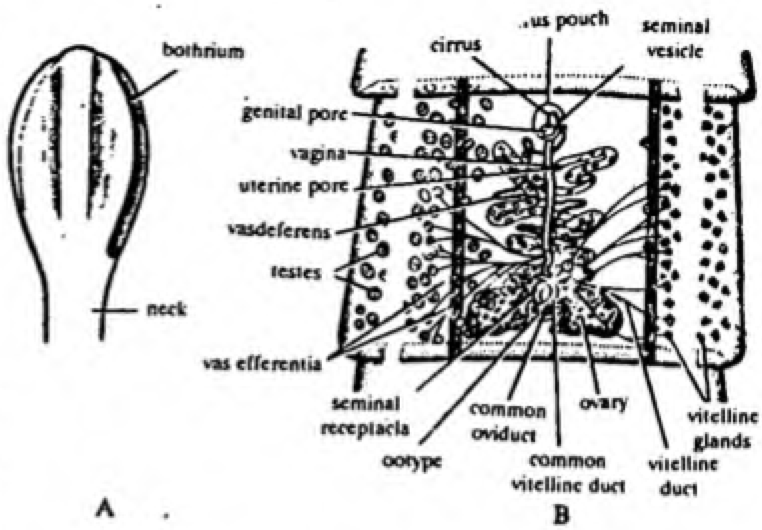

Fig. 30.22 *Diphyllobothrium*. A—Scolex, B—A mature proglottid.

9. Gonopores ventral.
10. Life-cycle involves two intermediate hosts, one is *Cyclops* (a copipod) and other a fish.
11. It causes bothriocephalus anaemia, erythropenia and haemorrhage.

MONIEZIA

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Taenioidea
Genus	-	*Moniezia*
Species	-	*expansa*

1. It is found in sheep, cattles and other ruminants.
2. Body is divisible into scolex, neck and proglottids.
3. The scolex is small with prominant suckers. The rostellum and hooks are absent.
4. Each proglottid is broader than long and contains a double set of reproductive organs.
5. Genital ducts are dorsall to osmoretgulatory canals.
6. Testes are numerous scattered throughout the centre of proglottid. Cirrus in cirrus pouch.
7. Ovaries are in the form of an open fan. Uteri form networks.
8. On one side vagina is dorsal to cirrus pouch and on other ventral.

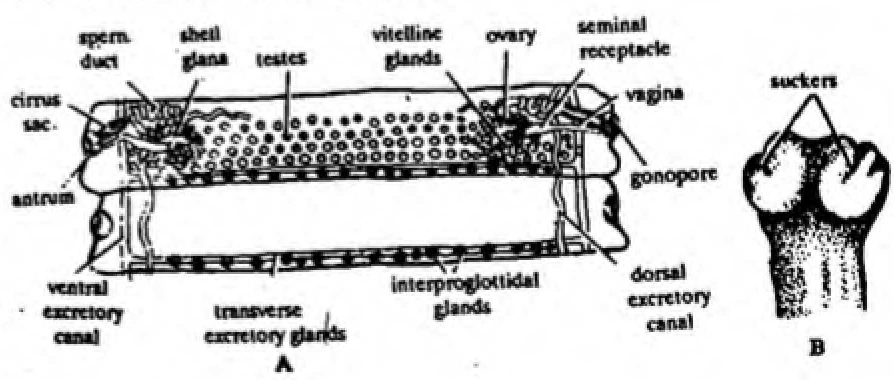

Fig. 30.23 *Moniezia*. A—Two proglottids, B—Scolex.

9. The uterus develops as a network of canales, but latter breaks up into a large number of uterine capsules, each enclosing 3-30 embryos.
10. Intermediate host is dog-fleas, *Ctenocephalus canis* and *Pulex irritans.*

TAENIA SAGINATA

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Taenoidea
Genus	-	*Taenia*
Species	-	*saginata*

1. It is commonly called the beef tapeworm. It lives in the intestine of man where beef is eaten.
2. The body is dorso-ventrally flatenned and much larger than *Taenia solium.* It measures 15-20 feet in length.
3. Body is divisible into scolex, neck and proglottids.
4. Scolex bears four large suckers for adhesion and devoid of rostellar hooks.
5. About 1000 proglottids are present.
6. Testes are about 300-400. Ovary in the form of two lobes. Ootype is present surrounded by Mehli's gland.
7. Life-history is similar to *T. solium.*
8. Intermediate hosts are cattles.

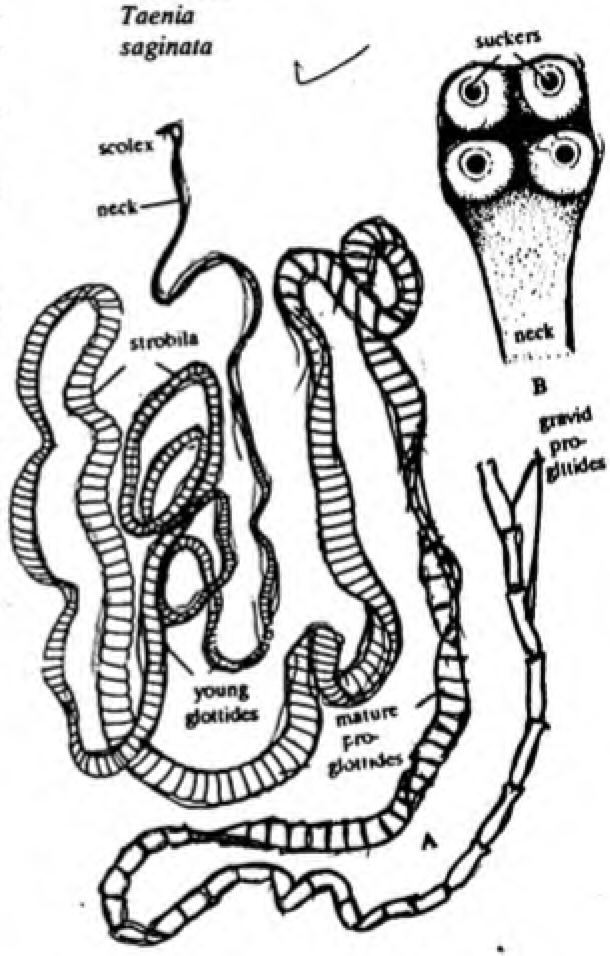

Fig. 30.26 *Taenia saginata.*

9. The intermediate host is mite (*Galumna*).
10. It is not so pathogenic but sometimes may cause diarrhoea or anaemia.

HYMENOLEPIS NANA

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Taenoidea
Genus	-	*Hymenolepis*
Species	-	*nana*

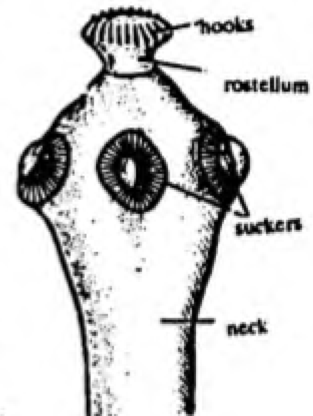

Fig. 30.24 Scolex of *Hymenolepis*.

1. It is commonly called the dwarf tapeworm of man. It lives in the intestine.
2. It is world-wide in distribution.
3. It measures 25-40 mm in lengths and has about 100-200 proglottids.
4. The rostellum is well-developed and retractile. It bears a single circlets of 20-30 hooks.
5. Neck is long and slender.
6. There are three testes with varying arrangement. Cirrus pouch is large with external and internal seminal vesicle and with an accssory sac.
7. Life-history is simple without any intermediate host.
8. The inner membrane of the hexacanth bears long, wavy filaments.
9. Larvae develop in the intestinal villi while the adult lives in the intestine.
10. It causes abdominal pain and diarrhoea.

DIPYLIDIUM CANINUM

Phylum	-	Platyhelminths
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Taenioidea
Genus	-	*Dipylidium*
Species	-	*caninum*

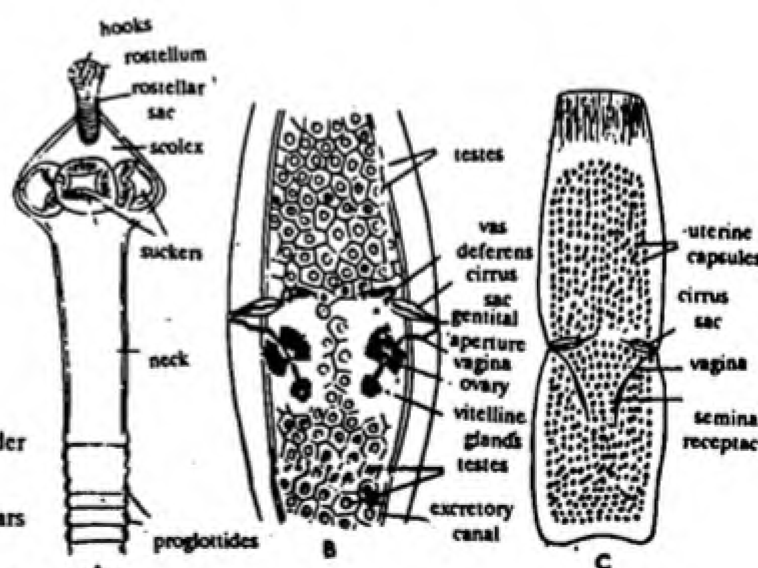

Fig. 30.25 *Dipylidium.* A—Anterior part, B—Mature proglottis, C—Ripe proglottis.

1. It is commonly called dog-tapeworm.
2. It has world wide distribution.
3. It lives in the intestine.
4. It measures 15-40 cm in length and has under 200 proglottids.
5. The scolex is somewhat triangular and bears four deeply cupped suckers.
6. Rostellum is retretile into a rostellar sac in scolex. It bears about 60 hooks in 3-7 rings.
7. Mature proglottids are long and barrel shaped having a double set of male and female sex organs. The genital pores at the middle of both lateral margins.
8. Numerous testes are present before or behind the female genitalia.

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DUGESI$ (PLANARIA)

Planaria or *Dugesia* belongs to class Turbellaria. The Turbellarians are mostly free-living, unsegmented flatworms that are clothed with a cellular epidermis, which is usually ciliated, sometimes only in parts. Turbellarians are primarily aquatic, and the great majority are marine. Although there are a few pelagic species, most of them are bottom dwellers that live in mud or sand, under stones and shells, or on sea weeds, *Degusia* is among them. The following description mostly belongs to the common fresh water genus, the *Degusia* formarly called *Planaria*. It is a well-known representative of the Turbellaria.

SYSTEMATIC POSITION

Phylum	-	Platyhelminthes
Class	-	Turbellaria
Order	-	Tricladida
Family	-	Planariidae
Genus	-	*Dugesia*

Habits and habitat

Dugesia is commonest free-living Platyhelminthes. They are usually found on the vegetation or under the stones in ponds, lakes, marshes, rivers and small streams. They generally inhabit pure, cool and clear water. Some species remain in currents, while others like to remain in quiet water. When active, they glide over the surface but when at rest they crawl down to the bottom or under other smooth objects, where light is not bright. *Dugesia* is found under the stone generally attached in great numbers, if pieces of meat are dropped in water near the back.

If starved they become smaller, but if well-fed they lay cocoons containing eggs which hatch to give young. They are carnivorous and extremely cannibalistic.

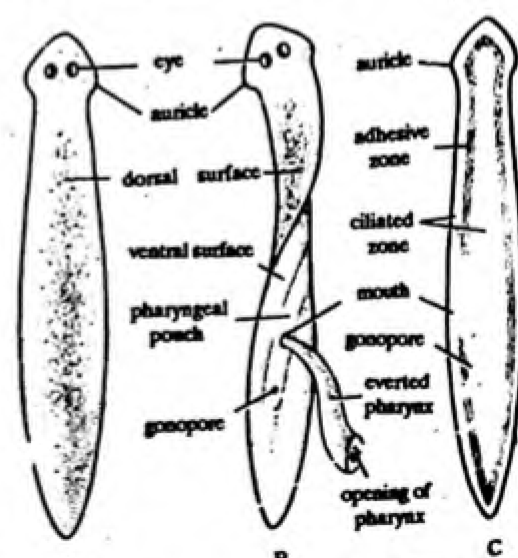

Fig. 31.1 *Dugesia*. External features. A—Dorsal view, B—Lateral view, C—Ventral view.

MORPHOLOGY

Shape, Size and Colour

These are small, thin, dorsoventrally flatenned, bilaterally symmetrical animals measuring about 12 mm long. Colouration is due to the dissolved pigments present beneath the epidermis. The colour may be dark yellow or olive, brown or blackish-brown and may have stripes of white, orange or yellow colour. The colouration is light or whitish on ventral side.

Structure

There are two ends in the body. Anterior end is blunt, while the posterior end is tapering. Anterior end is almost square or triangular with its apex pointing forward. This portion of the body is known as *head*, because with it animal moves forward. There are two lateral projections, called 'auricles or ears' at the base of the head. But these ears are not sensory

organs. On the dorsal side of the head, near the anterior end, there are two black *eye-spots*. Behind the auricles the body is somewhat constricted to form a so called *neck*. On the ventral side of body, near its middle, is found the mouth through which *proboscis* or *pharynx* protrudes. Thus, in *Dugesia* mouth is not situated on the head. The muscular walls of the pharynx serve for capturing the food. Behind the mouth in mature worms is situated a small *genital pore*. There are also excretory openings, the *nephridiopores*, on the dorsal surface situated laterally, but they are very minute and are, therefore, invisible. The ventral surface of the body is covered with cilia, which help in locomotion.

BODY WALL

The body of a planarian is covered by a ciliated epidermis. The epidermal cell on its free surface also show a number of microvilli. Cilia are more prominent on the ventral surface. The epidermal cells rest on a basement membrane. Among the epidermal cells the following other types of cell are also present:

(i) *Gland cell* secreting adhesive substances.

(ii) *Rhabditogen cell* which secretes and contains rhabdites.

(iii) *Sensory cell.*

Rhabdites are arranged at right angles to the body surface. They are hyaline elliptical structures secreted by rhabditogen cells. When they are expelled out they swell on contact with water forming a sticky froth around the body. This may be protective, help in gliding or even in capture of food. Some workers like *Reisinger* and *Kelbetz* (1964) suggest that the rhabdites and nematocysts are evolutionarily related.

Below the epidermis are granules and rods of pigments. The gland cells are unicellular, some occur in the epidermis but most of them are in the mesenchyme. They have long necks opening on the surface and secrete mucous.

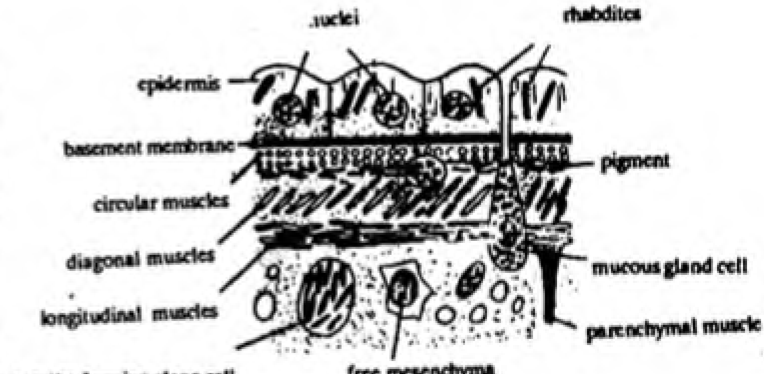

Fig. 31.2 *Dugesia*. T.S. of body wall to show ciliated epidermis and muscle layers.

Below the epidermis is a thin elastic basement membrane at which the epidermal cells rest. It maintains the general form of the body and provides surface for the attachment of underlying muscles.

The muscle layer consists of outermost this sheet of *circular muscle fibres*, middle broad *diagonal muscles* and innermost is the *longitudinal muscles*. On the ventral body wall the longitudinal muscles are more developed as this surface is important in the locomotion of the animal. Some muscle fibres run dorsoventrally in mesenchyme.

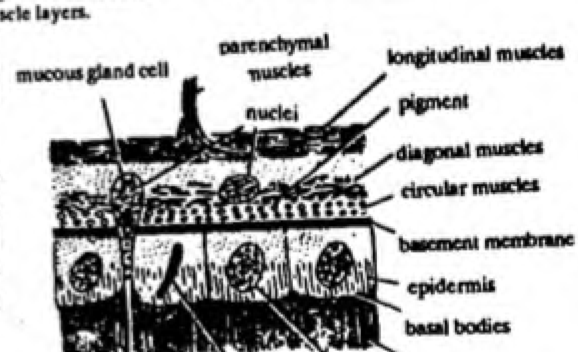

Fig. 31.3 *Dugesia*. V.L.S. Ventral body wall.

Mesenchyme. The bulk of body-wall and the interior is filled with mesenchyme, which consists of connective tissue (net-like syncytium containing nuclei), free wandering cells and fluid filled spaces. The wandering cells multiply by mitosis and differentiated into other types of cells. These cells help in regeneration in the *Dugesia*. Parenchyma or mesenchyma helps in transport of food, assimilation and in the excretion of waste products.

PHYSIOLOGY

Locomotion

Dugesia is aquatic but it does not swims. The animal exhibits two types of movements.

1. Gliding movement

2. Crawling movement

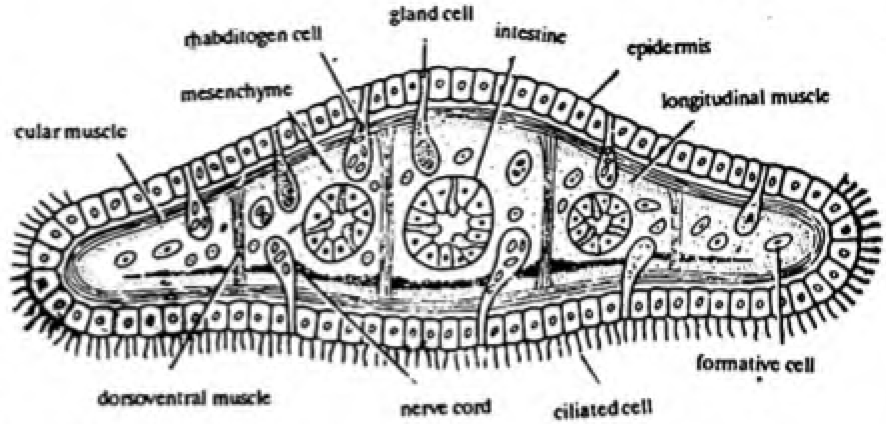

Fig. 31.4 *Dugesia.* T.S. body showing the disposition of muscles, nerve cord etc.

1. *Gliding movement.* In gliding movement cilia present on the ventral surface beat against a track of mucus secreted by the mucous glands. As a result of ciliary action, the animal is propelled forward in a gliding manner. The wave of ciliary action proceeds from the anterior to the posterior end and the head of the animal is slightly elevated.

2. *Crawling movement.* It is brought about by the contraction of muscles. The wave of contraction extends from anterior to the posterior end, contraction of circular and dorsoventral muscle elongate the body, the anterior is held fixed to the substratum by mucous and the posterior end is then pulled forwards by contraction of longitudinal muscles.

Sometimes transverse waves of contraction sweep the length of the body causing its undulations in the vertical plane and enabling the *Planaria* to crawl forward. Differential action of local muscle groups produces turning or twisting movements.

DIGESTIVE SYSTEM

Alimentary canal. The alimentary canal is incomplete i.e. there is only one opening for ingestion and egestion. The alimentary canal comprises: mouth, pharynx and intestine.

Mouth. The mouth is an oval or rounded aperture situated mid-ventrally a little behind the middle of the body. It is surrounded by radial and circular muscle fibres from the subepidermal musculature. The muscle fibres regulate the opening or closing of mouth. It leads into a large cylindrical elongated chamber. The *pharyngeal pouch.*

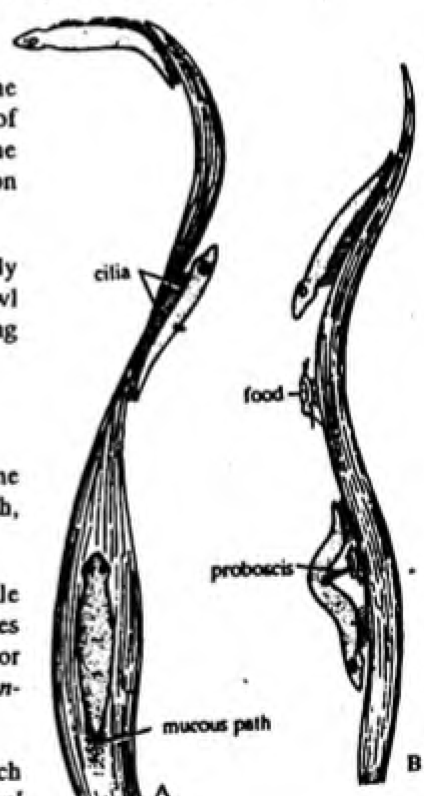

Fig. 31.5 *Dugesia.* A—Locomotion, B—Feeding.

Pharynx. The pharynx is a tubular organ situated within the pharyngeal pouch projects posteriorly. The pouch is bounded by a muscular sheath, the *pharyngeal sheath.* A space sometimes called buccal cavity is present between mouth and the opening of pharynx. The free end of the pharynx projected out of the mouth during feeding. The projecting pharynx is called *proboscis.* This is brought about by the action of muscular wall. Pharynx opens into the *intestine* by way of a short *oesophagus.*

Intestine. The intestine immediately divides into three branches. The median branch extends forwards upto the head while the other two lateral branches extend backwards upto the posterior end, one on either side of pharyngeal cavity. All the three branches give off numerous branching and blind diverticulae which end into the mesenchyme. The much branching intestine is a means of increasing the surface area for digestion, absorption and distribution of food.

Histology of alimentary canal. The pharyngeal wall shows a complicated histological structure. It consists of nine layers from the surface to the lumen : epithelial cells, longitudinal muscle layer, circular muscle layer, outer gland cells, nerve plexuses,

inner gland cells, longitudinal muscle layer, circular muscle layer and an endodermal epithelial lining.

The intestine is simple and thin consists of a single-layered epithelium, the gastrodermis. The gastrodermal cells are of two types *phagocytic cells* and *granular cells.*

Food and feeding. Normally *Dugesia* is *holozoic* and canivorous subsisting for the most part on crustaceans, insect larvae and small worms. During feeding, it glides through the action of cilia and the adhesive glands secrete adhesive secretion. When prey comes in contact with the secretion it becomes firmly adherent. *Dugesia* then folds the anterior end of its body over the prey and thus immobilizes it. The pharynx is then produced out through the mouth and through its peristaltic action sucks up small particles of the prey into its intestine.

Digestion. Digestion is initially extracellular. Food is broken down by pharyngeal proteolytic enzymes and endopeptidases secreted by the gland cells lining the intestinal wall. The broken pieces of partially digested food are then digested by intracellular method. The phagocytic cells of the intestine engulf these particles which are digested by intracellular endopeptidases inside cytoplasmic vacuoles in acidic medium. After about 8 hours the vacuolar content becomes alkaline and digestion in this medium is completed by exopeptidases, lipases and carbohydrases. The excess of food is stored as fat and proteins in the intestinal cells and mesenchyma.

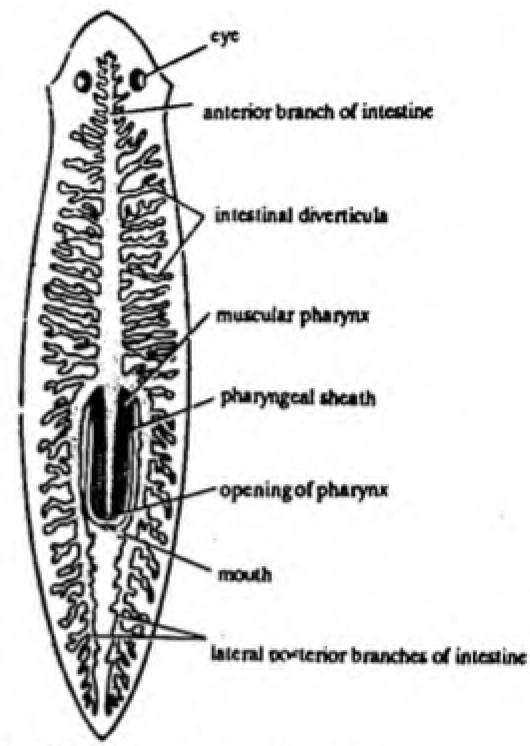

Fig. 31.6 *Dugesia.* Alimentary canal.

Freshwater planarians are able to withstand prolonged experimental starvation. In extreme cases, they utilize part of enteron and all the mesenchyma and reproductive system. In fact, the body volume may be reduced to as little as 1/300 of the original.

Egestion. Since there is no anus, the egestion of undigested food material takes place through mouth. It is brought about by the contraction of the muscles of body-wall.

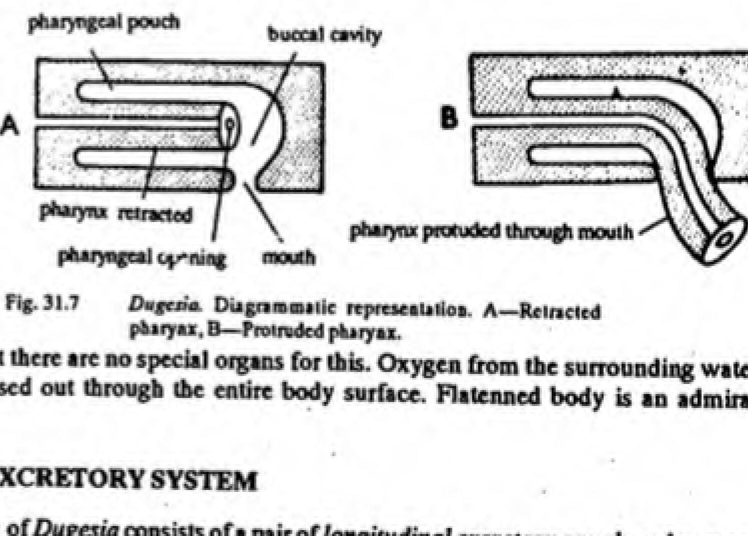

Fig. 31.7 *Dugesia.* Diagrammatic representation. A—Retracted pharynx, B—Protruded pharynx.

Respiration. Mode of respiration is aerobic but there are no special organs for this. Oxygen from the surrounding water is directly into the body and carbon dioxide is diffused out through the entire body surface. Flatenned body is an admirable adaptation for this type of respiration.

EXCRETORY SYSTEM

The excretory system or *protonephridial system* of *Dugesia* consists of a pair of *longitudinal excretory canals* and numerous tiny enlargements known as flame cells.

(i) **Excretory canals.** A pair of longitudinal excretory canals running on each side of the body throughout the length. They are highly inter-coiled and open to the dorsal surface by several minute pores called nephridiopores. Anteriorly two canals are united by a *transverse vessel,* in front of eyes. Each canal divides into a number of branches which further divides into very fine blind *capillaries* which bear flagella at the inner end (*Wilson* and *Webster,* 1974). The terminal structure is composed of flame cells or *cryptocytes.*

(ii) **Flame cells.** Each *flame cell* represents the unit of excretory system. It is a large, tubular, protoplasmic body. It is

produced into numerous protoplasmic processes reaching the mesenchynme. Its terminal part is swollen into a bulb and contains a conspicuous nucleus. The flame cell has an intracellular space which is continued into capillaries. The space encloses a bunch of cilia which vibrate giving the appearance of flickering candle flame.

Besides the flame cells, certain glandular cells called the *arthrocytes* or *paranephroytes* occur in close contact with the excretory canals and also help in removal of excretory products.

Physiology of excretion. Excretory substance is collected from the mesenchyme and is transferred into the cavities of flame cells. The beating of cilia of flame cells causes hydrostatic pressure by which the fluid waste passes into the longitudinal trunks and goes out of nephridiopores.

According to *Storer, Woleott, Guyer, Hickman* etc. the flame cells simply help in excretion of nitrogenous wastes. But according to some workers like *Mekanna*, 1968; *Prusch*, 1976 etc. the excretory system in *Dugesia* is largely osmoregulatory bailing out excess of water. As osmoregulatory organs, the protonephridia might function in the following manner. The beating of cilia of flame cells would produce a negative pressure within the end of the tubule, causing filteration of fluid across the membrane covering the fenestrations. Selective reabsorption of ions, especially K+ and Cl-, by the tubule would yield a hyposmotic fluid.

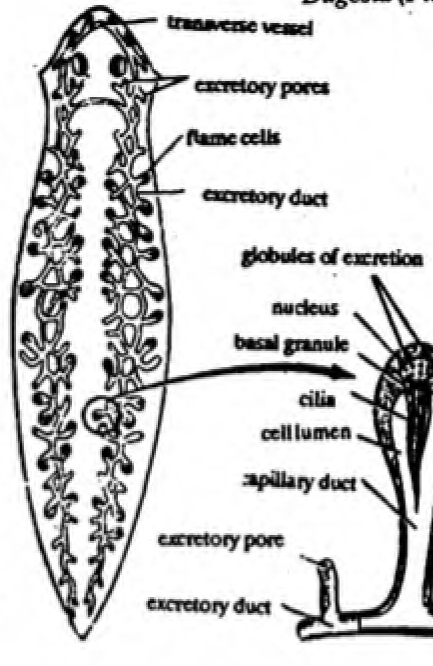

Fig. 31.8 *Dugesia*. Excretory system.

NERVOUS SYSTEM

The nervous system shows a much better development than what we found in the coelenterates and can be differentiated into the *central* and *peripheral systems*.

Just below the epidermis and behind the eyespots, there is a bilobed *brain* or *cerebral ganglia* in the form of an inverted 'V'. Both the ganglia are connected by several transverse fibres. From the brain, several thin nerves are given off anteriorly and to the eyes. From the brain two *lateral longitudinal nerve cords* extend posteriorly along the ventral side. The two nerve cords are connected together by *transverse connectives*.

The peripheral system is present in the form of a *sub-epidermal plexus* (just below the epidermis) and a *sub-muscular plexus* below the muscle layers in the mesenchyme.

The nerve-cells or neurons may be unipolar, bipolar or multipolar. All the neurons possessing neurites are similar. These neurites cannot be differentiated into axons and dendrons.

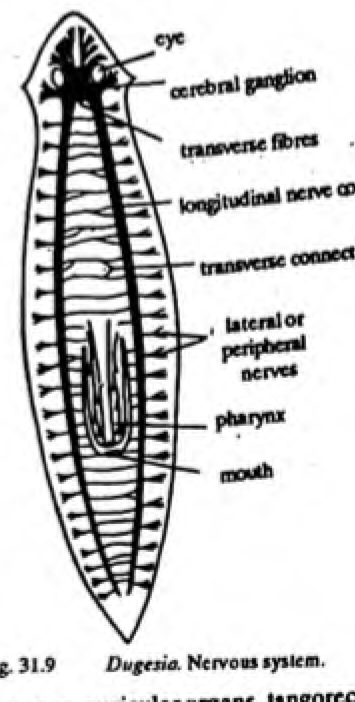

Fig. 31.9 *Dugesia*. Nervous system.

SENSE ORGANS

Dugestia possesses special sensory organs, called receptons. These are photoreceptors or eyes, auricular organs, tangoreceptors and rheoreceptors.

(i) **Photoreceptors or eyes.** The eyes are two dark spots on the dorsal surface of the anterior end, one on either side of the median line. Each eye has the form of a cup whose opening face anterio-posteriorly.

Structure of each *eye* is very simple. It is made up of highly pigmented *retina*. Inside the cup are situated numerous nerve-cells, the *fibrillae* of which are in contact with the retina and their opposite ends are continued into an optic nerve, which

is joined with *brain.* The nerve cells enter the cup through the opening. Ectoderm over the eye is not pigmented. *Lens* is absent in eye.

Eyes are capable of a crude discrimination of the direction of light. The pigment cup serves as a shield and light can enter only through its opening to stimulate the photosensitive expanded ends of retinal cells, thus the animal can detect the direction light. The animal is negatively phototactic and is most active at night. If the eyes are removed it can still react to light. However, the reaction is much slower. This shows that it possesses some light sensitive cells over the general body surface.

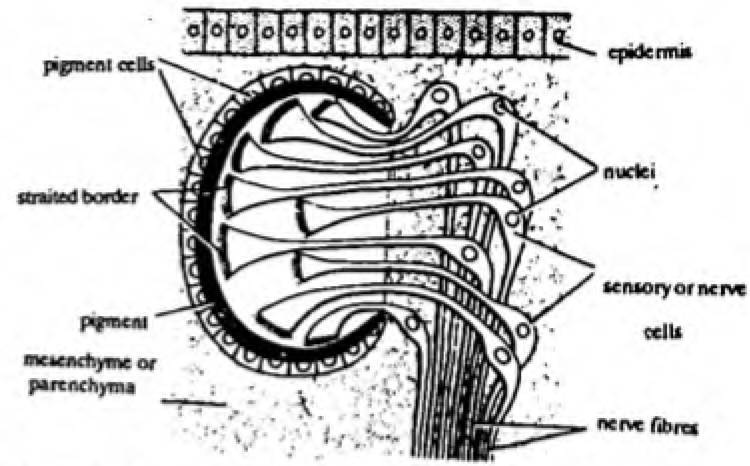

Fig. 31.10 *Dugesia.* V.S. of eye.

(ii) *Ciliated pits.* Besides eyes, there are *ciliated pits* which are also sense-organs. They are situated on either side of the head, having special sensory cells with long cilia. These ciliated pits are connected with nervous network. Tentacles, which are found in some turbellaria with long cilia, are also supposed to be organs of chemical sense, which help in finding food.

(iii) *Auricular organs.* These are sensitive to chemical and are chaemoreceptors. These are in the form of a pair of whitish ciliated groores, lying one on either side of the head near the base of the auricles. If the auricles are removed the planarian cannot locate food.

(iv) *Tangoreceptors.* These are sensitive to touch temperature etc. A tangoreceptor is a small cell with fine sensory bristles that project over the surface except on that posses to the brain. They are particularly concentrated on the ventral surface around the mouth, auricles and the body margins. Thus ventral surface is positively thigmotactile while the dorsal surface is negatively thigmotactic.

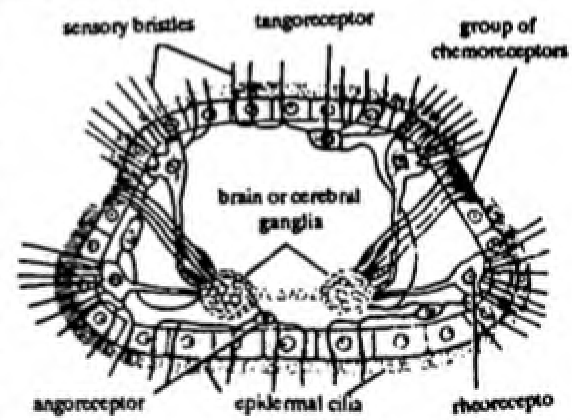

Fig. 31.11 *Dugesia.* Digrammatic. T.S. Showing various receptors.

(v) *Rheoreceptor.* These are sensitive to water current. They are of general occurrence and their sensory processes or bristles project much beyond the level of cilia.

REPRODUCTIVE SYSTEM

Dugesia reproduces asexually as well as sexually.

(1) Asexual Reproduction

Asexual reproduction occur by the transverse binary fission. The plane of fission usually forms posterior to the pharynx. The posterior part attaches to substratum by mucous, the anterior part stretches forward until the animal snap into two. Each half regenerates the wanting parts resulting in the formation of two complete planarians. Some planarians fragment into two or more pieces each growing into a complete individual. Asexual reproduction is restricted to some species only. Some species reproduce asexually in one season, and may develop sex organs in the other, but there are some species that reproduce exclusively asexually and rarely develop sex organs.

(2) Sexual Reproduction

The reproductive organs are more complicated in these animals. The gonads i.e. testes and ovaries are derived from the meroderm and there is a system of tubules and chambers in which fertilization occurs.

The animal reproduces in early summer and the gonads are developed temporarily in the breeding season. The *Dugesia* is

bisexual or hermaphrodite but self-fertilization does not take place and the cross fertilization is the rule. After breeding season the gonads degenerate and disappear and the worm reproduces asexually.

Male reproductive organs. They consist of a large number of small spherical testes, which are situated on both the sides of the body. Each testis is connected with minute tubes, called *vasa efferntia*. These form two large ducts called *vasa deferentia*. The two vasa deferentia run parallel to one another towards the posterior end, where these bend mesially towards the penis. Each vas deferens dilated to form the *seminal* or *spermiducal vesicle* with thick muscular wall. The sperms are stored here. The penis shows two regions, the anterior large spherical *penis bulb* and the posterior narrow conical *penis papilla* with muscular wall. The lumen of penis is very narrow and called *ejaculatory duct*. The penis papilla opens into the genital atrium which terminates in the common gonopore, situated midventrally behind the opening of mouth. The lumen of penis bulb is formed by *bulbar cavities*. The bulb contains numerous *unicellular* glands, the prostate glands which open into its lumen.

Female reproductive organs. The female reproductive organs consist of a pair of *ovaries*, which are small spherical bodies situated laterally just behind the head. From each ovary arises an oviduct which extends posteriorly through the parenchyma. Immediately after its emergence each oviduct presents a dilation, which is known as *seminal receptacle*. The two oviducts unite to form a common vagina which opens into the *genital atrium*. The oviducts along their whole length are surrounded by numerous vitelline glands which open into oviducts by short *vitelline ducts*. Because of the close association of oviduct and vitelline glands, these are sometimes collectively referred to as the *ovovitelline ducts*. Opening into the genital chamber is found a muscular sac-like *copulatory sac* or *uterus* or *bursal canal*. The bursal canal opens into a large sac the *bursa copulatrix* which receives penis and temporarily stores the sperms received during copulation. It opens below into female genital atrium.

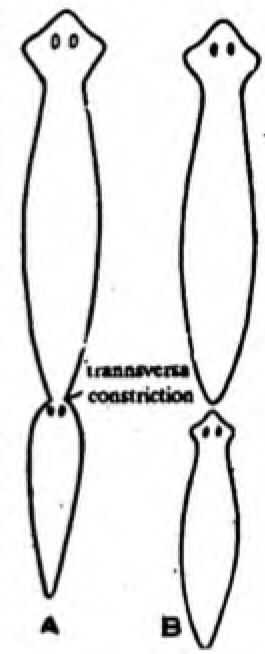

Fig. 31.12 *Dugesia*. Transverse binary fission.

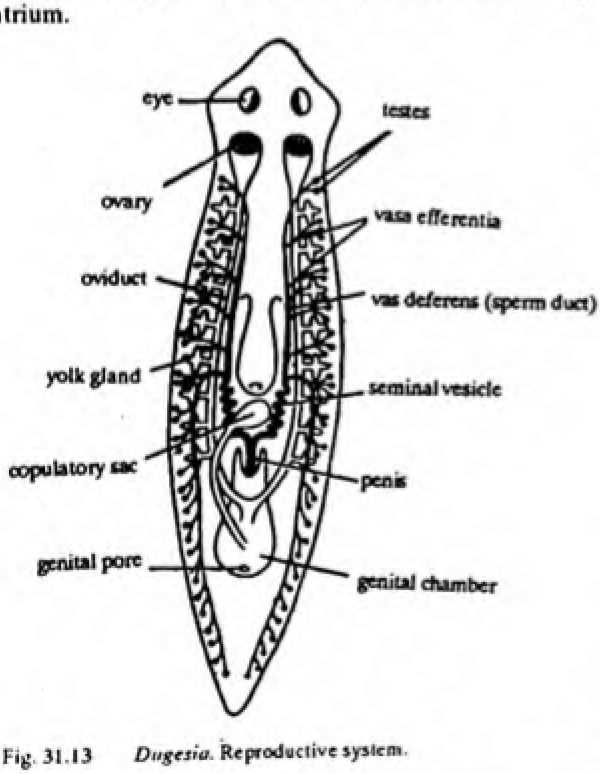

Fig. 31.13 *Dugesia*. Reproductive system.

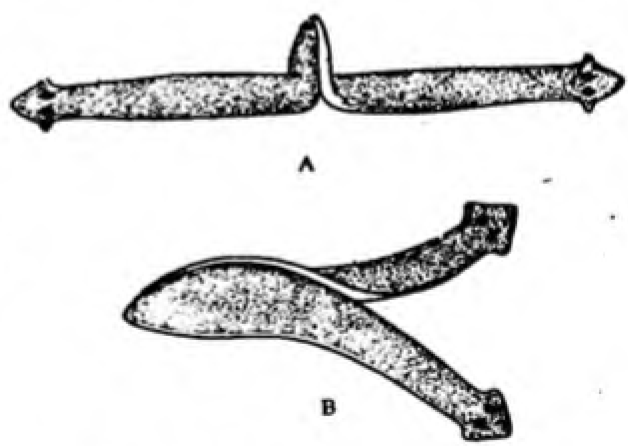

Fig. 31.14 *Dugesia*. Copulation.

COPULATION

Although *Dugesia* is hermaphrodite, yet *cross-fertilization* is a rule. *Copulation* takes place between the two worms in which their posterior and ventral surface come together and the penis of each is inserted into the *genital atrium* of the other. In this way sperms are deposited in the *seminal receptacles* of the mating partner. The sperms are stored inside the copulatory sac for some time and then travel along the oviducts to reach the seminal receptacles. The eggs are deposited in the seminal receptacle and are fertilized. Thus the fertilization is internal. During breeding season, each worm may copulate many times.

Cocoon formation

The zygote thus formed, pass backwards through the ovovitelline ducts and reach the genital atrium of female. In their way they are mingled with yolk cells which are discharged by yolk glands into the oviducts. The diposition of yolk outside the zygote is unique condition in Platyhelminthes. Such eggs are called *ectolecithal*. When the eggs are reached in genital atrium 5-10 eggs along with yolk cells are enclosed in a protective, proteineous shell forming a cocoon or an egg-capsule. The capsule is coated by a sticky substance secreted by the cement glands that surround and open into the common genital atrium. The capsule is now extruded through the genital pore. As it is passing out, sticky coating is drawn out into a sticky stalk that fastens it to some object chiefly the under surface of stones. The capsules are laid in succession at intervals of a few days.

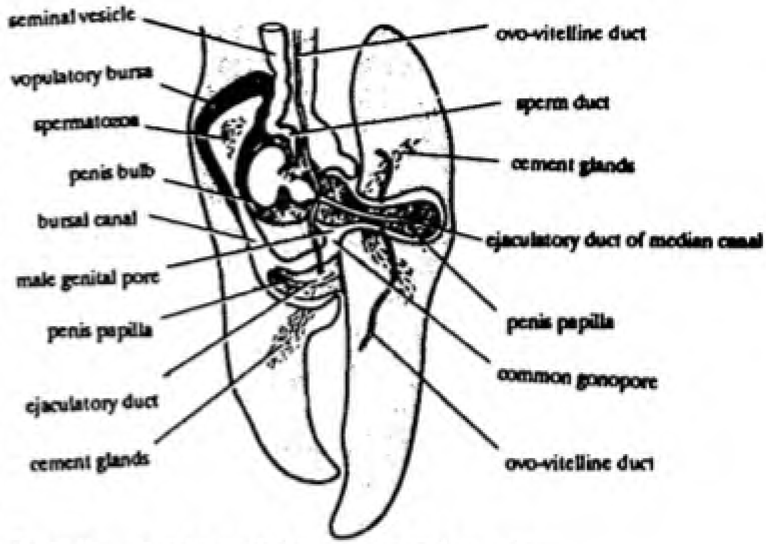

Fig. 31.15 *Dugesia*. A pair of copulating animals in section.

Development

Development start soon after the cocoon is laid and the hatching occurs in 2 to 3 weeks depending upon the temperature of water. The cleavage is *spiral* and *determinate* type. No larval stage is formed hence the development is *direct*. A young *Planaria* or *juvenile* glides out of the capsule from each egg.

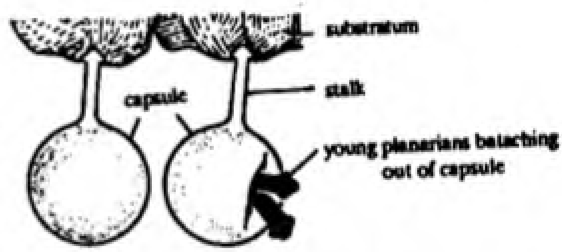

Fig. 31.16 *Dugesia*. Young one haching from the cocoon.

Regeneration

Like *Hydra*, *Dugesia* shows extensive regeneration. The lost parts can be easily replaced. If the animal is cut transversely into two halves, the anterior half regenerates a new tail, while the posterior half regenerates a new head. If the animal is cut into three pieces, the middle piece will regenerates head on the anterior side and a tail on posterior side. The regenerating piece retains the original *linear polarity* of the whole animal. Regeneration involves *epimorphosis* and *morphollaxis*, the original parts fit to function with the regenerated parts in the new individuals.

Power of regeneration is maximum near the head and minimum near the posterior end, this is associated with the metabolic rate. The metabolic rate is highest in the head and becomes progressively lower towards the tail. This variation in metabolic rate and regeneration power is called *axial gradient (Child)*.

Regeneration is brought about by the free formative cells or *neoblasts* of the mesenchyme. These cells migrate to the cut surface and by repeated division

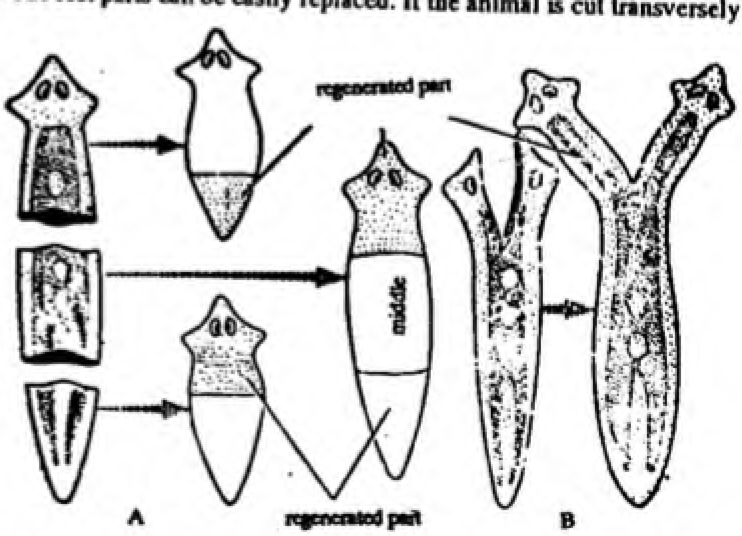

Fig. 31.17 *Dugesia*. Regeneration. A—Transverse, B—Longitudinal.

produce new tissues.

Regeneration is always not perfect. If a sexually mature *Dugesia* is cut transversely between its pharynx and copulatory apparatus, its reproductive organs degenerate and fail to regenerate, but each half grows into asexual animal.

Dugesis shows a *lateral polarity*. If the anterior end is cut longitudinally, each part will grow into a complete head. Thus several headed monster results. The phenomenon is called *hetermorphosis*.

32

FASCIOLA HAPATICA

Fasciola belongs to class Trematoda. Most of the trematods living in other animals inhibit the digestive tract or its accessory tubes or cavities, and it seems probable that those species living outside gut are derived from gut dwelling forms. Probably the most important of these flukes, *Fasciola hepatica*, is the first digenetic fluke to have its life-cycle uncovered. *Thomas* (1883) described its life-cycle. *Reinhard* (1957) redescribed its life-cycle in an interesting way.

SYSTEMATIC POSITION

Phylum	-	Platyhelminthes
Class	-	Trematoda
Order	-	Digenia
Family	-	Fascioliodae
Genus	-	*Fasciola*
Species	-	*hepatica*

GEOGRAPHICAL DISTRIBUTION

World wide distribution occurs in areas where sheep, cattle and goats are raised and there is a niche for lymnaied snails. In U.S.A., organisms found in the Gulf Coast, the North-West, Rocky Mountains, Florida etc. In U.S.A., it is endemic.

HABITS AND HABITAT

Fasciola hepatica is derived from Greek and Latin words - (L., *fasciola* = small bandage; Gr., *hepar* = liver) is a *digenetic parasite*, i.e., its life history is completed in two hosts - a primary vertebrate host and a *secondary* or intermediate invertebrate host. Adult *F. hepatica* occurs in the liver and bile passages of the primary host which is usually sheep; but, at times, it may occur in some other vertebrates, like goat, horse, dog, ass, ox, deer, antelope, rabbit, elephant, monkey, etc. Humans are occasional host for *F. hepatica*, and infections are most often obtained through eating watercress (*Nasturtium officinale*) in salad. A single host may harbour as many as about 200 of these flukes in its liver, which may consequently cease to function normally. This effect is known as liver-rot. *F. hepatica* spends a part of its life history in an intermediate host, a freshwater snail which is either *Limnea truncatula* or some specific species of *Planorbis, Fossaria, modicella, Pseudosuccinea* etc.

Shape, Size and Colouration. The body is large, soft and fleshy. It is dorsoventrally flatenned and leaf-like having somewhat oval appearance. The size varies from 1.8-5.1 cm in length and about 0.4-1.5 cm in breadth near the mid body. The colour of body is generally pinkish. The margins are blackish or brownish due to the presence of vitelline glands. The alimentary canal is brownish in colour due to the presence of ingested bile of the host.

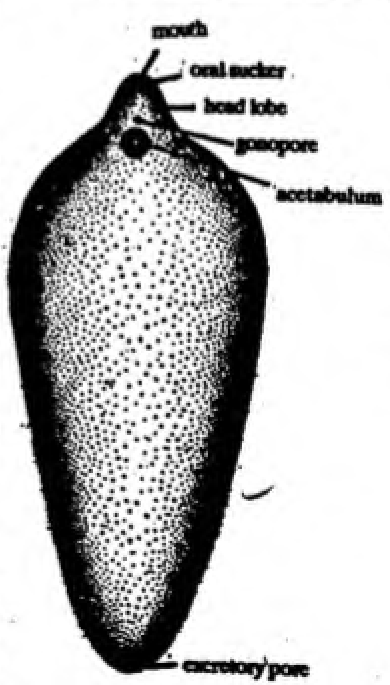

Fig. 32.1 *Fasciola* hepatica. External features.

Structure. The *anterior end* of *F. hepatica* is triangular while *posterior end* is tapering. The anterior end terminates into a projection, which is called *apical* or *cephalic cone* or *head lobe.* At the apex of the head lobe is situated a small opening, the *mouth,* which is surrounded by an anterior muscular sucker, called *oral* or *anterior sucker.* At a short distance behind the head lobe is situated another saucer-shapted sucker known as *ventral sucker* or acetabulum, situated on the ventral side. The ventral sucker is superficial and has no connection with the interior of the body.

Fasciola hepatica was formerly known as *Distomum hepaticum* and the name of the group to which it belongs was known as *Distomidae.* These names were adopted as the mouth and anterior sucker were regarded as two suckers or two mouths (*di,* two; *stoma,* mouth). The word *stoma* was used in trematodes for suckers, which are characteristic structures. But now it is certain that the mouth cannot be claimed as a sucker.

On the dorsal surface there is a single aperture in the middle line at about one-third of the length of the animal from the anterior end. This aperture is the opening of *Laurer's canal.* This aperture appears during breeding season.

BODY WALL

Body wall in *Fasciola* is characteristic and adapted to parasitic mode of life. It lacks a cellular epidermis and consist of the following layers:-

1. **Cuticle.** It is the outermost layer having stout, rough, blunt scales which project over the general surface. Cuticle is a secretion of *mesenchyme,* either of special type of cells called gland cells formed between muscle-fibres or of general mesenchyme. Cuticle is definitely non-chitinous and is made up of *scleroproteins.* It is situated over the body and protects the liver-fluke from the harmful effects of the different types of juices produced in the host. Below the cuticle is situated a thin transparent layer known as *basement membrane.*

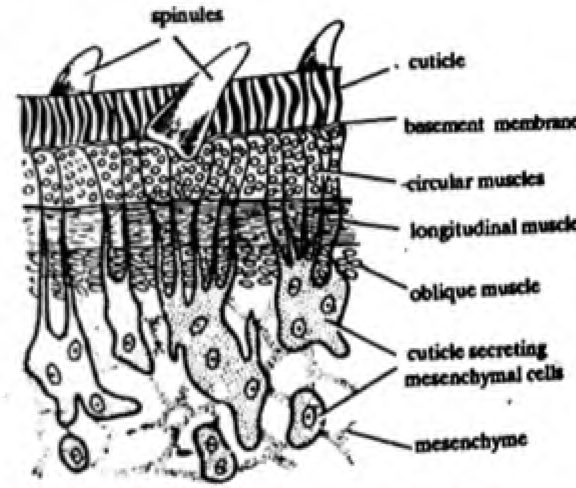

Fig. 32.2 *Fasciola.* V.L.S. body wall seen under light microscope.

2. **Musculature.** Immediately beneath the cuticle are three layers of muscles - the outermost circular layer, the median longitudinal layer and the inner digonal layer. In addition to these muscles others make up the suckers and pharynx. Still others, the parenchymal muscles, are dorsoventrally oriented along the lateral regions of the body.

3. **Parenchyma or mesenchyma.** Immediately benath the musculature are numerous cells, known as *beta cells* or *mesenchymal cells.* Some of the beta cells possess cytoplasmic tubules that penetrate through the muscular layers and reach the cuticle. These specialize beta cells are thought to secrete cuticular materials that reinforce the existing cuticle.

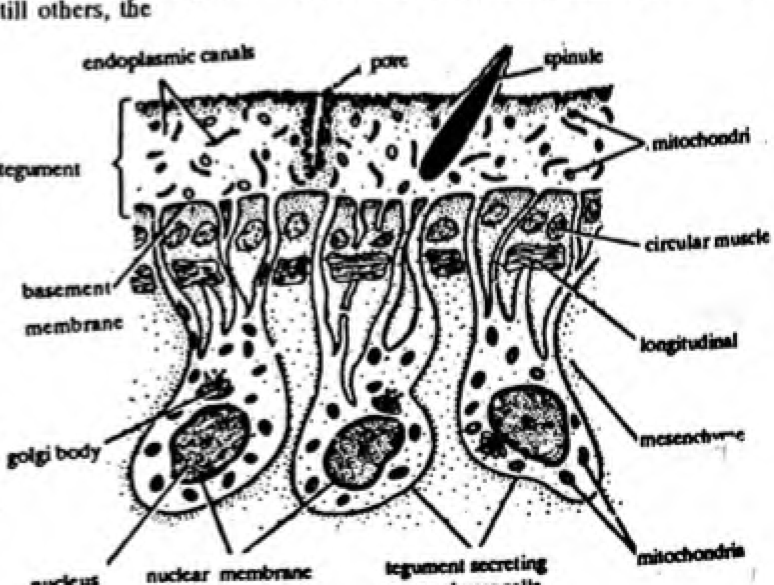

Fig. 32.3 *Fasciola.* V.L.S. body wall seen under electron microscope.

Electron microscopic studies by *Threadfgold* (1968) have revealed that the so called *cuticle* of *Fasciola* is actively a thick layer of multinucleated protoplasm containing mitochondria, canals of endoplasmic reticulum, vacuoles and vesicles. It is termed as *tegument.* It is continuous with *tegument secreting cells* lying embedded in the mesenchyme. The outer surface of tegument is thrown into numerous folds. These increase the

surface area considerably for the absorption of fluids of the host. Further, tegument is perforated by fine *pore canals*. Through these canals fluids are absorbed into the mesenchyme.

Functions. The body wall of *Fasciola* is more than an inert protective layer, it is a dynamic structure of great importance in the metabolism of the organism. Although the animals derive a great deal of their nutrients through ingestion, certain chemicals such as certain amino acids, which are necessary as energy sources and as raw materials for the synthesis of complex body chemicals, are absorbed through the body wall. It is also possible that certain metabolic wastes are discharged through cuticle.

DIGESTIVE SYSTEM

The digestive system is complex and highly branched with *mouth* but no *anus*. It consists of the following parts:

Mouth. It is a small opening situated ventrally at the apex of head lobe and surrounded by oral suker.

Oral chamber. Mouth opens into a short but funnel-shaped oral chamber.

Pharynx. It leads into a short, rounded, muscular pharynx with thick wall and pharyngeal glands.

Oesophagus. The pharynx communicates with a short-narrow oesophagus joining the intestine.

Intestine. The intestine immediately bifurcates into two lateral branches, running one on either latera side of the body upto the posterior end where these end blindly. A large number of caeca or diverticula are given out along either side of its whole length. The diverticula of the outer side are large and highly branched, while those of the inner side are short and unbranched.

Food and feeding. The food of *Fasciola* is bile and blood as it lives in the bile passage of sheep and cattles. It takes about 0.18-0.2 ml of blood per day. Small microscopic debris is also taken as food. The food is taken by the sucking effect of the pharynx and is pumped into the intestine.

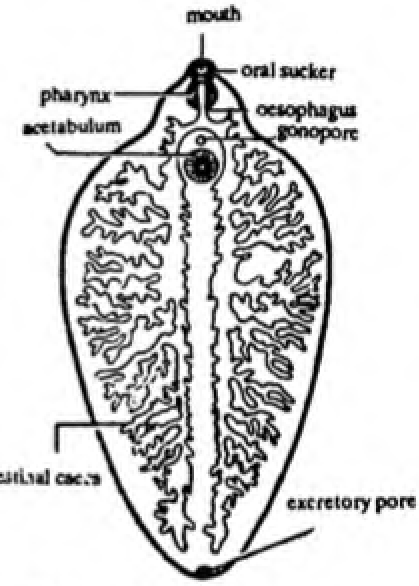

Fig. 32.4 *Fasciola*. Digestive system.

Digestion. The exact manner of food digestion is not well understood. Digestion is supposed to be extracellular, carried in the intestinal ceaca. Proteolytic enzymes are reported in the animal. The digested food is diffuses into the surrounding mesenchyme. The mesenchyme distributes digested food to every part of body. As earlier mentioned the tegument also helps in the absorption of certain amino acids as well as monosaccharides (glucose and fructose). The reserve food material is in the form of glycogen and fat which are stored in mesenchymal cells and muscles.

Egestion. As there is no anus, the undigested food materials are egested out through mouth.

Respiration. In the *Fasciola*, the respiratory organs are absent so that the respiration takes place through general body surface by the process of diffusion. Since the animals is an endoparasite, the rate of respiration is very low and is *anaerobic*. In this process, there is no necessity of oxygen. Glycogen undergoes anaerobic glycolysis to form pyruvic acid. Pyruvic acid is decarboxylated to form carbon dioxide and an acetyl group. The latter combines with coenzymes to form acetyl coenzymes A. Acetyl coenzyme A is finally condensed and reduced to form fatty acids. During the process energy is released.

EXCRETORY SYSTEM

The excretory system consists of flame cells or protonephridia connected with an intricate system of excretory ducts.

1. Excretory ducts. A single and median longitudinal excretory canal which runs just behind the ventral sucker and terminates into the *excretory pore*. It is ramified throughout the body. In the anterior region it riceives two ventral and two dorso-lateral excretory canals. The dorsal ducts before opening into the main longitudinal excretory canals are united so as to

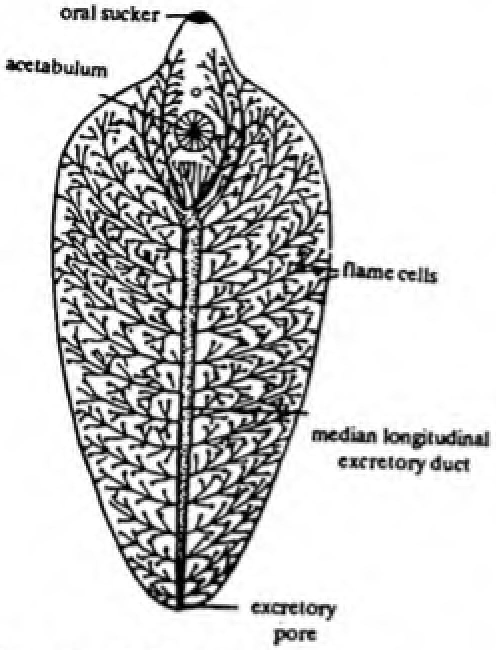

Fig. 32.5 *Fasciola*. Excretory system.

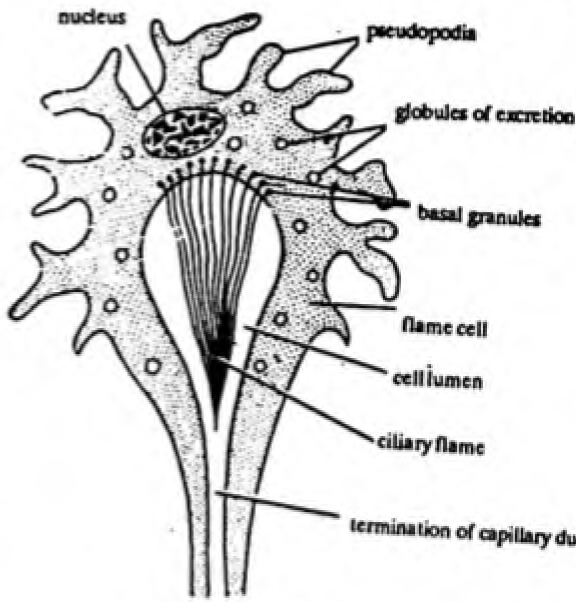

Fig. 32.6 *Fasciola*. A flame cell.

form a common duct. Main excretory canal as well as dorsal and ventral-lateral excretory canals divide into small capillaries or tubules, each of which ends internally into a *flame cell.*

2. **Flame cells.** The flame cells are characteristic, each has a thin elastic wall with a nucleus and a cavity containing many long cilia arising from basal granules or blepharoplasts. The cilia in a living animal vibrate like the flickering of the flame, hence named as flame cells. The cavity of flame cell is continued with the cavity of capillary. The shape of these cells is irregular due to pseudopodial processes into the mesenchyma.

Physiology of excretion

The excretory products are carbon dioxide fatty acids and ammonia. These are diffused into the flame cells from the surrounding mesenchyme. The fluid moves through the tubule by the action of cilia into the excretory ducts and finally passes out of the body through the excretory pore. All the ducts except the median longitudinal duct are lined with cilia. The course of the flow of excretory products is as follows:

Excretory products-- mesenchyme -- flame cells

Main longitudinal canal vessels twigs capillaries

Excretory pore -- outside.

NERVOUS SYSTEM

The nervous system is well developed in spite of the fact that due to sluggish and parasitic habitats such a large correlation is not need. The nervous system includes:

(a) **Central nervous system.** Two cerebral ganglia are prominant masses of nervous material joined together by a nerve ring around the

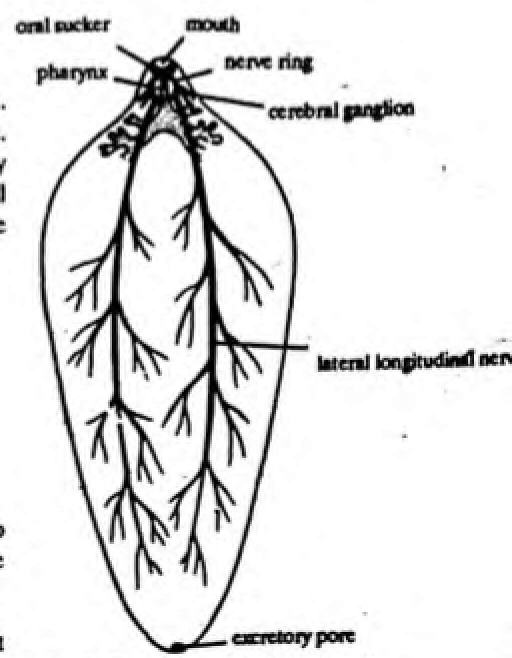

Fig. 32.7 *Fasciola*. Nervous system.

oesophagus. From each cerebral ganglion arise three longitudinal nerve cords, dorsal, ventral and lateral. Of these the lateral nerves are much longer than the other. They alone reach the posterior end of body. They are interconnected at intervals by transverse commissures.

(b) **Peripheral nervous system.** From each cerebral ganglion three nerves arise anteriorly and innervate the head lobe and the oral suckers. Fine nerves arise from nerve cords all along their course and supply the various parts of the body.

SENSE ORGANS

Due to parasitic mode of life, special sense organs are absent. It however, possesses tectile organelles or *tangoreceptors.* These are bulb-like nerve endings. These are abundant in the sucker region.

Hormones in Fasciola

In *Fasciola* serotonin is present and it seems to play a role in the tissues comparable to that played by adrenalin in mammalian tissue. It is not known whether serotonin acts as a humoral component of the nervous system as it is reported to do in some other animals. The tissues of *Fasciola* contain an acetylcholine-like substance and cholinesterase; the specificity of cholinesterase for acetylcholine has not been established (but it has been suggested that these components are related to activity of nervous system.

Insulin has been reported to have an effect on the carbohydrate metabolism but the evidences are lacking.

REPRODUCTIVE SYSTEM

Fasciola hepatica is hermaphrodite or dioecious. The gonads are well developed and the male and female genital ducts open into a common chamber, the *genital atrium.* It is situated anteriorly in the body and opens to the exterior through the common genital aperture or gonopore, located ventrally in front of the acetabulum.

1. The Male Reproductive Organs

The male reproductive organs are:

(i) A pair of testes

(ii) A pair of *vasa deferentia*

(iii) Seminal vesicle

(iv) An ejaculatory duct

(v) Cirrus and cirrus sac.

(i) *Testes.* These are greatly ramified and tubular structures situated in the middle part of the body, one behind the other (*tandem arrangement*).

(ii) *Vasa deferentia.* A narrow delicate duct, the *vas deferens*, emerges out from each testis and runs forward to meet the fellow of opposite side forming the common sperm duct just below the ventral sucker.

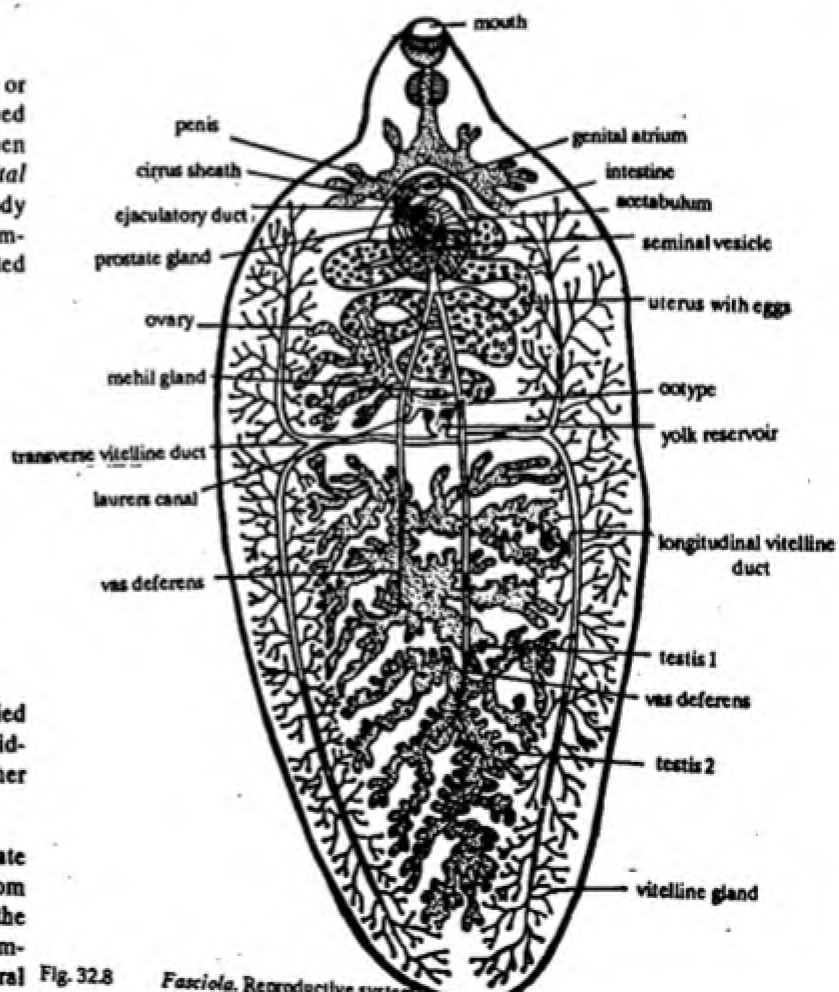

Fig. 32.8 *Fasciola.* Reproductive system.

(iii) *Seminal vesicle.* The common sperm duct immediately leads into a large muscular pear-shaped sac, the *seminal vesicle*, which lies in front of ventral sucker.

(iv) *Ejaculatory duct.* The ejaculatory duct arises as a fine convoluted tube from the seminal vesicle and runs forward in a zigzag fashion through the cirrus to open into the *genital chamber* through the *male genital pore.*

(v) *Cirrus and cirrus sac.* The cirrus or penis is a muscular cylindrical structure traversed internally by the passage of ejaculatory duct. It can be everted out and drawn in through the genital pore and thus helps in copulation. The cirrus and the seminal vesicle both are enclosed in a bag-like *cirrus sac.*

(vi) *Prostate glands.* Numerous unicellular prostate glands are found around the ejaculatory duct.

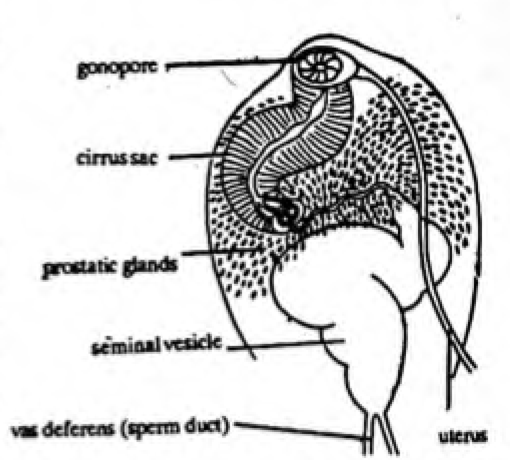

Fig. 32.9 *Fasciola.* Details of male reproductive system.

(B) Female Reproductive Organs

The female reproductive organs are:

(i) Ovary

(ii) An oviduct

(iii) Uterus

(iv) Laurer's Canal

(v) Mehli's gland

(vi) Vitelline glands and vitelline ducts

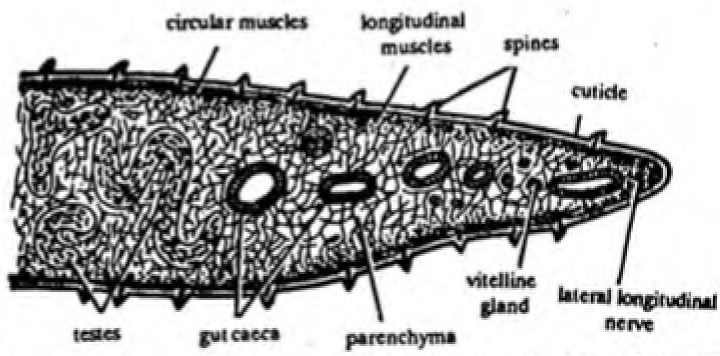

Fig. 32.10 *Fasciola.* T.S. body through male reproductive system.

(i) *Ovary.* The ovary is a large, highly branched tubular structure which is situated on the right side in front of testes in the mesenchyme. It occupies the anterior one-third of the body.

(ii) *Oviduct.* From the inner side of ovary arises a short, narrow and convoluted duct, the *oviduct.* It runs down ward to join the uterus.

(iii) *Uterus.* It is a long wide and highly convoluted tube that extends upto the genital atrium, opening into it through the female genital aperture, close to male genital pore on the left-side. It contains a large number of capsules containing fertilized eggs.

(iv) *Laurer's canal.* The Laurer's canal arises from the oviduct and acts as a sperm duct. It develops a temporary opening on the dorsal body surface during breeding season. It may serves as vagina.

(v) *Mehli's gland.* At the junction of oviduct, vitelline duct and uterus a mass of unicellular gland lies known as *Mehli's glands.* The function of these glands remains unclear. It was believed that these glands were merely responsible for the formation of shell but *Stephenson* (1947), *Rennison* (1953) and *Johri* and *Smyth* (1955) have shown definitely that this cannot be the case, because the shall of eggs is rich in various proteins, phenols and phenolases that are not present in these glands. Several views have been proposed to explain the function of Mehli's glands:

(a) These glands secrete a fluid enchances the hardening or tanning process of newly formed eggs. (b) The secretion of these glands cause release of the shell globules from the vitelline glands. (c) The secretion forms a thin membrane around the cells forming eggs, and the shall globules than built up from within this membrane (d) The secretion libricates the uterus facilitating passage of the eggs. (e) The secretion activates sperms which are passed down. All or some of these hypothesis may be valid.

(vi) **Vitelline glands and vitelline ducts.** The vitelline glands or the yolk glands are in the form of numerous minute vesicles or follicles arranged on either side of the body from one end to the other. A fine duct arises from each vesicle and after uniting with similar ducts from other vesicles opens into the *lateral longitudinal ducts*. The two longitudinal ducts are connected in the middle line by a *transverse vitelline duct*. A median duct arises medially from the transverse vitelline duct and joins the oviduct.

The functions of vitelline glands is now know. In addition to contributing yolk material for incorporation within the egg, the vitelline glands also secrete large globules known as *shell globules* - which envelop the developing egg and eventually coalesce and become hardened to form the shall. The hardening process involves the tanning of protein present within the coalesced globules by quinone. Thus vitelline glands contribute both yolk and shell material.

Ootype. In some cases the oviduct after receiving Laurer's canal and a common vitelline duct swelles to form ootype. In *F. hepatica* according to *Stephenson* (1947) the ootype is absent.

LIFE HISTORY

Copulation and fertilization. Cross - fertilization takes place by insertion of cirrus of one fluke into the Laurer's canal of another fluke. Transference of biflagellate sperms directly into the oviduct is possible. Secretion of prostate glands and as mentioned above, the secretion of Mehli's gland keep the sperms active for fertilization. Laurer's canal become invisible after copulation. Fertilization takes place in oviduct. Self-fertilization is also seen here the sperms enter the uterus of same fluke through female genital pore and pass down to reach oviduct where fertilization takes place.

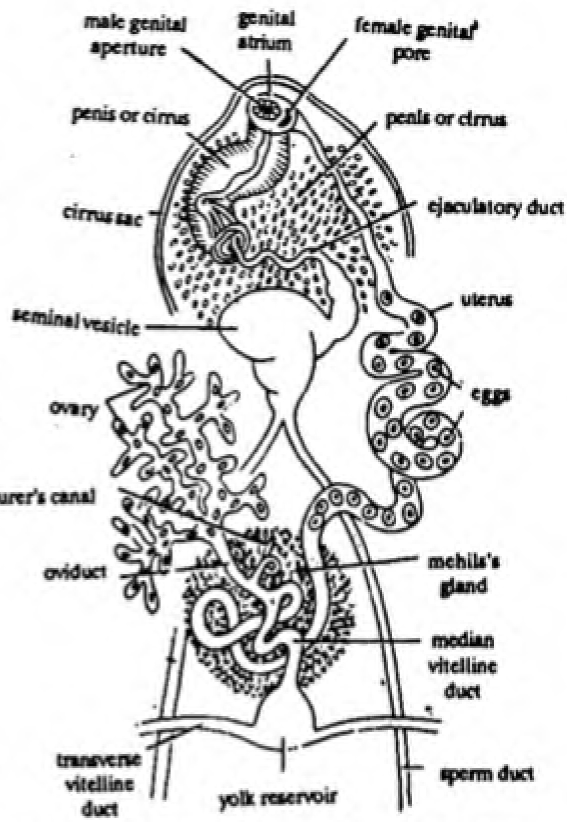

Fig. 32.11 *Fasciola.* Details of male and female reproductive system.

Fertilized egg gets about 30 or so yolk - cells and shell globules from vitelline glands by the way of various vitelline ducts. The shell is formed with a lid or *operculum* on one side. *Rowen* (1956, 57) demonstrated that there is a viscous granular cushion at the opercular end of the egg, situated immediately beneath the operculum. The zygote and a mass of yolk - cells enveloped by the shell constitute the capsule. When complete the *capsule* passes into the uterus.

Phenolase

Phenol ------------------> quinone ----------> Tanned protein

Protein ------------------> protein

Capsule formation occurs throughout the year and one fluke may produce about 50,000 capsules. A single fluke may produce a total of 2,00,000 capsules in about 11 years.

The capsules differ in shape and size in different animals. Hence, with the size and shape of capsules the parent flukes are recognized.

Development. Clevage starts immediately after fertilization. The fertilized egg divids into a small granular *propagative cell* and a large ectodermal *somatic cell.* Somatic cell divides and gives rise to the body-wall of the larva. Propagative cell later on divides into a cell similar to *somatic cell*, which takes part in

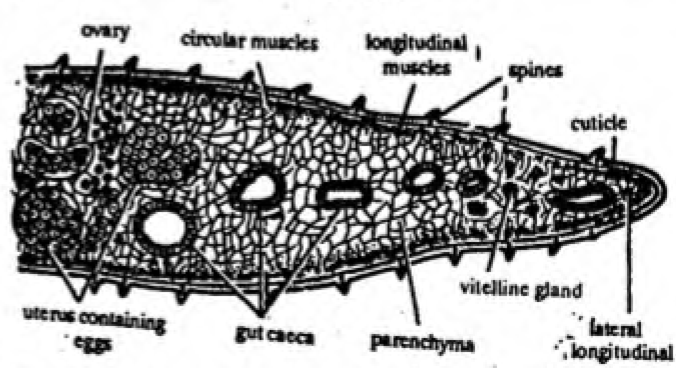

Fig. 32.12 *Fasciola.* T.S. body through ovary and uterus.

the development of mesoderm, endoderm, and a cell called *germ cell* afterwards reaches the posterior part of the body and forms germ-ball consisting of 14 to 20 germ cells.

Capsules then escape through the gonopore and are liberated into the bile capillaries from where they reach the intestine of the host and are passed out with the faeces.

The development remains arrested while the embryos remain in the faeces, they may survive in wet faecal matter for several months. If washed free, the development of the embryo proceeds. The optimum temperature for development ranges from 10 - 30°. At 30°C the encapsulated embryo differentiates into *miracidium larva* within eight days. The availability of oxygen is also a factor. The fully formed miracidium is a more or less conical little animal covered with ciliated epithelium. It does not look at all alive an adult fluke but does show resemblance to some free-living flat worm.

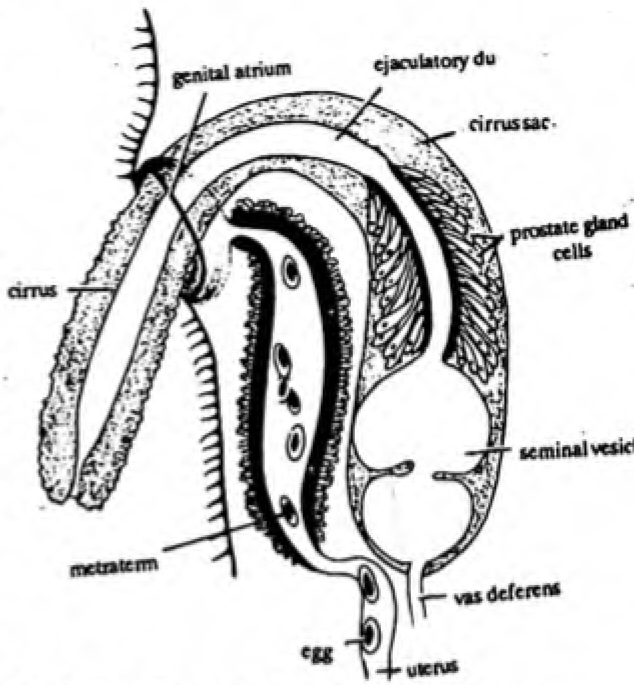

Fig. 32.13 *Fasciola.* Shows cirrus coming out of gonopore.

Miracidium larva. As the miracidium is formed the hatching enzyme is secreted in response to exposure to light. The enzyme dissolves the cementing material by which the operculum is attached, thus releasing the operculum. Expension of the granular cushion, accompanied by exosmosis of salts and other materials from within the egg pushes off the operculum. The hatching occurs in water and free-swimming miracidium penetrates the intermediate host.

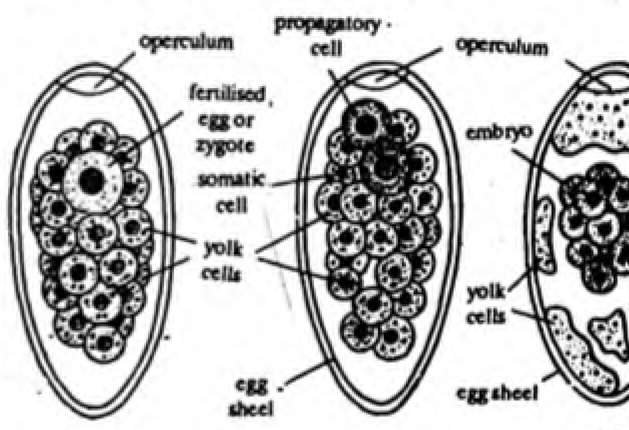

Fig. 32.14 *Fasciola.* Early stages of developmeent. A—Fertilized egg, B—Two cell-stage, C—Many cell stage.

Structure of miracidium. It is an elongated, about 0.07 mm long creature with a broad anterior end and a narrow posterior end. Anteriorly there is a *conical* or *apical papilla* or terebratorium. It is cliated except in the region of apical papilla. However, anterior cilia are slightly longer.

The ectoderm is formed by 21 hexagonal plate like cells which are arranged in 5 rows. The I row consists of 6 small plates. The II row contains again 6 plates, III row has 3 plate cells, 4 plates in IV row and 2 plates in V row. The arrangement of the ciliated plates is quite constant and is of considerable value in determining phylogenetic relationships. In *F. hepatica* the cells of first row arranged are two dorsal, two ventral and two lateral in position. The cells of second row are three dorsal and three ventral. In the third row the cells are one dorsal and two venterolateral. The fourth row has two right and two left cells and the fifth row has one left and one right cells.

The ectoderm is followed by musculature consisting of outer circular and inner longitudinal muscle fibres. The musculature is followed by a layer of cells forming the sub-epithelium. The ectoderm, musculature and sub-epithelium forms the body wall of larva.

At the anterior tip of the miracidium is found a mobile apical papilla. A pair of *cephalic glands* or *penetration glands*, located in the mesenchyme, empty to the outside near the apical papilla. The secretion of these glands aids in dissolving the host's tissue during penetration process. Besides a sac-like multinucleated *apical gland* is located between the two cephelic glands. Previously it was supposed to be the gut of larva.

The sensory organs of miracidium includes two eye-spots. Eyes contain pigments and are situated at the surface of the second row of epidermal plate over the brain. The eyes may be primary receptors involved in the process of hatching. When kept in dark few miracidia hatch, but illumination rapidly induces hatching. The *brain* of the miracidium is a large cephalic ganglion lying in the parenchyma behind the apical region. It is X-shaped. From this nerve centre, fibres are oriented in all directions to innervate the various body tissue.

There is a pair of flame-cells or protonephridia, which are excretory organs and their ducts open to the outside between IV and V rows of epidermal plate cells.

During the differentiation of the miracidium within the egg shall, certain germinal cells become trapped in the parenchyma. These develop into germ balls by increasing in number and size and becoming enveloped, eventually giving rise to the next larval generation. Such germ balls are usually located in the posterior region of the body.

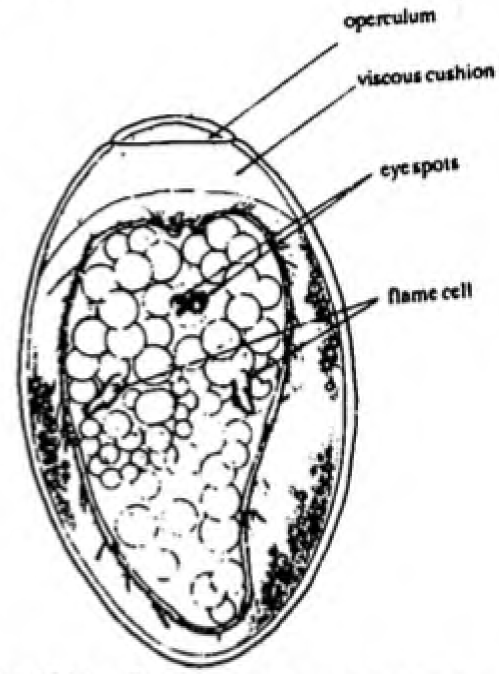

Fig. 32.15 *Fasciola*. Miracidium just before hatching.

Miracidium swims about in water or moisture film, where cattle usually pass out their faeces. It dies in 30 hours unless it is able to reach intermediate host, which is always an amphibious snail of the genus *Limnaea*. Intermediate host in case of *Fasciola indica* is *Limnea acuminatisata* while in the case of *Fasciola hepatica* intermediate host in *Limnea truncatula*. When larva enters the tissue of the intermediate host with the help of apical papilla, it reaches soft parts, such as mantle, pulmonary sac and hepato-pancreas. Penetration into the intermediate host is helped by the secretion of the penetrant glands or other glands. On reaching the intermediate host, ciliated epidermal cells are cast off, while eyes and brain are lost. Larva swells up and changes in shape and size, so as to become a sac-like structure, called sporocyst. Germ-balls of miracidium do not disintegrate.

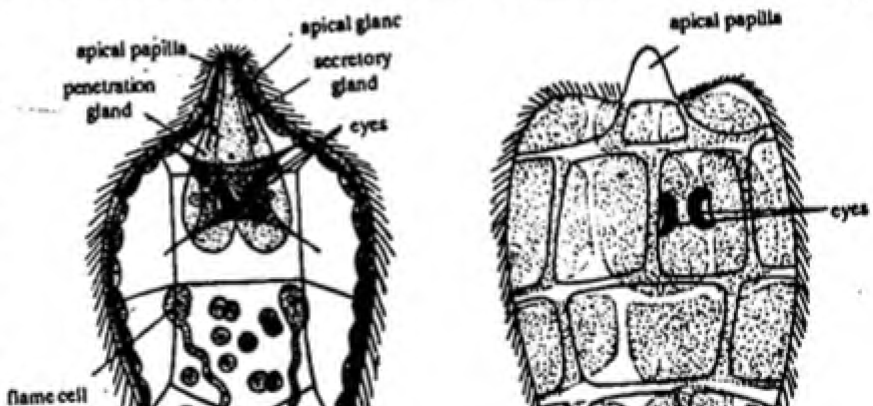

Fig. 32.16 *Fasciola*. Miracidium in ventral and dorsal view.

Sporocyst. The sporocyst is an elongated, hollow, sac-like larva. Its body wall consists of non-cellular cutile followed by musculature and sub-epithelium. The brood chamber is hollow space in the centre of the sporocyst within which are found the germ balls that eventually give rise to the next generation. Sporocyst contains no alimentary canal, nervous system or reproductive systems. The protonephridia are present opening laterally by pores.

The sporocyst moves about by muscular contractions in the host tissues, absorbing nourishment from themand causing them a considerable damage. Its germ balls develop into the next larval forms, the rediae. Each sporocyst produces 5-8 rediae. Some of the germinal cells are again set aside within the rediae for the formation of the next larval form.

Redia larva. The rediae emerge from the sporocyst by the rupture of body ball of sporocyst. Each radia is an elongated and cylindrical form, measuring 1.3-1.6 mm in length. It has a circular ridge, called collar near the anterior end and a pair of projections termed *lappets* near the posterior end. The body-wall consists of the usual cutile, musculature and subepithelium. Unlike the sporocyst, the redia possess a mouth located at the anterior terminal of the elongated body. The mouth leads into a muscular pharynx, which in term leads a blind-sac, the gut. Numerous unicellular pharyngeal glands open into the pharynx.

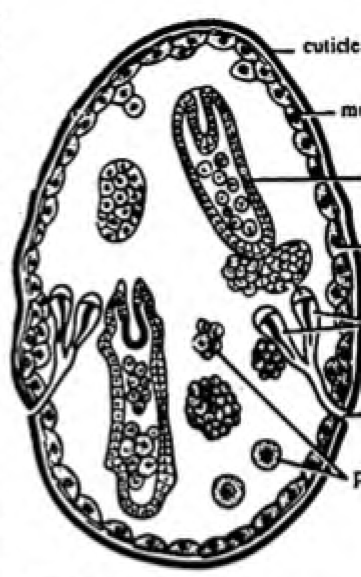

Fig. 32.17 *Fasciola.* Sporocyst.

Protonephridia divide further and form a much branched system. All the flame cells of one side open out through a common excretory duct. A birth pore is present, lateral to and in proximity of the mouth. Within the brood chamber are found germ balls.

Redia is a very active little creature. It moves about by the contractions of the body and lappets. It nourishes itself by sucking fluid and cells of the host tissues with its muscular pharynx. It soon migrates into the digestive glands of the snail. During summer months when the food is sufficiently available, mother rediae mature in 12-18 days, the germ balls give rise to a second generation of daughter rediae. Germ balls of daughter rediae in the winter develop into next larval stage, the cercariae.

Cercaria larva. Cercariae leave escape the mother or rediae through their birth pores. From each redia 14-20 cercariae are produced. Cercaria is about 0.25-0.35 mm long and is an oval larva with a tail. The body wall consists of cutile, musculature and subepithelium. On the anterior side, there is a mouth with a sucker, a suctorial pharynx, long oesophagus and a bifid intestine. A ventral sucker or acetabulum is present on the ventral side. A large number of dark, brown cells, called *cystogenous glands* are found beneath the cuticle. There is a pair of excretory ducts, each with several flame cells. These open near the hind end of the larva into a bladder that leads out through a pair of nephridiopores. A nervous system similar to that of adult has also appeared. Rudiments of reproductive organs develop from the germ cells near the hind-end.

From the digestive glands of the snail, the cercariae pass into the pulmonary sac and then escape into the surrounding water. Cercaria swims about 5 minutes to an hour in summer. Afterwards, it settles down on some green leaves of water plants. Tail is cast off and the body becomes rounded and forms around itself a thick brownish cyst wall from the cystogenous glands. The encysted cercaria is now called metacercaria.

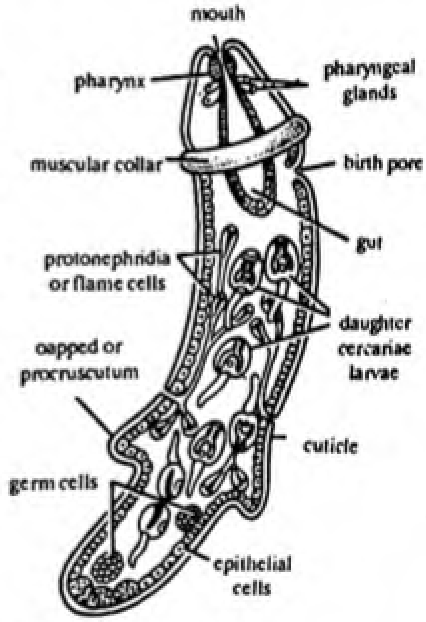

Fig. 32.18 *Fasciola.* Redia.

Factors affecting development in Snail

The rate of development in the snail host is a function of the environmental temperature. *Kendell* reported a curious effect of temperature on the development of *Fasciola*. In snails maintained at laboratory temperature, daughter rediae were not produced, the first generation of rediae giving rise to cercariae. On the other hand snails exposed daily to a period of low temperature i.e. 4-5°C, daughter rediae were produced from rediae.

The state of snail nutrition also affects development. The effect of food availability on development in the snail host is probably the explanation for the observation that fewer larvae develop in small snails than in large ones.

Metacercaria. It is a juvenile fluke having a rounded form with a diameter of about 0.2 mm. It resembles cercaria larva but differs from later in the absence of tail, cystogenous glands and presence of thick cyst wall. Excretory bladder opens directly

through a single pore.

The metacercaria, encysted on vegetation, may live for as long as a year at low temperature or for as short time as two or three weeks at 25°C.

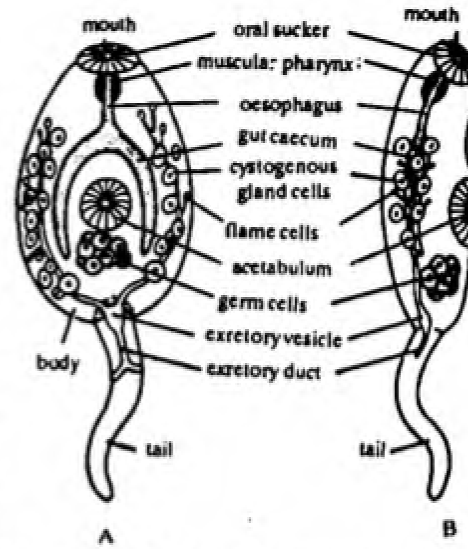

Fig. 32.19 *Fasciola*. A—Cercaria in ventral view, B—Cercari lateral view.

Inspection to final host

The final excystment in the host requires an elevated temperature i.e. 38°C, low redox potential, a high carbon dioxide tension, and the presence of bile. The factors necessary for the excystment of *Fasciola* matacercariae seem to serve as stimuli to activate the worms, but the mechanism is not clearly understood. When metacercaria reaches the intestine of host, the cyst is digested and young fluke is liberated. The young worm penetrate the wall of gut and passes into the peritoneal cavity. In the body cavity the young worms seem to move about rather aimlessly until they encounter the capsule of liver. On contact with the liver, the flukes burrow into it, devouring liver parenchyma as they move. It grows in size within 5-6 weeks and finally settles in the bile duct. It attains sexual maturity and begins to lay eggs 11-13 weeks after ingestion by the mammalian host.

Nature of life-history

The life-history of *Fasciola hepatica* is much complicated due to the occurrence of several larval forms in a series. Formarly, it was held that the rediae and cercariae develop by parthenogenesis from the propagatory or germ cells, which were believed to be the eggs (*Grobben*, 1882). This kind of asexual parthenogenetic reproduction by larval forms is known as *heterogamy*. This view was widely accepted for sometime and under its way, three terms were coined. These are *parthenitae* for sporocyst and rediae larvae, *adolescariae* for cercaria larvae, and *maritae* for adult flukes. This view, however, is now considered erroneous and has been given.

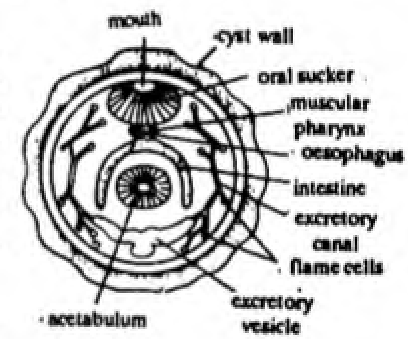

Fig. 32.20 *Fasciola*. Metacercaria.

It has been found that the germ cells represent in the larval forms are not eggs. Instead they are diploid cells derived by the mitotic divisions of propagatory cell which is separated from the sygote at its first cleavage. Thus it can be said that they are parts of zygote. It, thus, follows that one zygote produces several larvae. Thus, this process of reproduction in sporocysts and rediae has been looked upon as *polyembryony* by *Ishii* (1934), *Chen* (1937), *Rees* (1940) and *Cart* (1944). Since all the larvae resulting from a zygote are not formed simultaneously but at intervals, the phenomenon should be called delayed polyembryony.

Steenstrup (1942) and some other workers interpret polyembryony as a sexual multiplecation and hold that there is a alternation of sexual and asexual generation in life-history of *Fasciola*. But *Hyman* is of the view that it is a continuous ontogeny involving asexual multiplication in the larval stages.

Pathogenesis

Pathogenesis as a direct result of the flukes' activities may be either chronic or acute. Acute *fascioliasis* or *liver rot* occurs during the preadult migration of the flukes in the parenchyma of the liver, and sometimes other organs, for about 8 weeks. The most striking changes in acute fasciolosis are seen in the liver, where there are haemorrhagic flukes. The liver becomes swollen and in some instances, may become so swollen that the capsule ruptures. The by-products produced by worms are very toxic and cause *anaemia, diarrhoea, eosinophilia* etc.

Chronic fascioliasis occurs beyond 12 weeks, when the flukes have reached the bile ducts and are maturing sexually. Although milk and wool production looses are the usual results of chronic infections, deaths also occur.

The liver performs a vast array of essential functions in vertebrates, and it is axiomatic that liver damage will have a variety

of detrimental effects. The adult fluke causes anemia, haemorrhage and suppression in production of new red blood corpuscles. The result of liver damage is failure to gain weight in young animals, weight losses in older animals, reduced milk production and lowered fleece weights in sheep. The osmotic pressure of the blood is lowered and fluid is retained in the tissue spaces.

Treatment. Carbon tetrachloride has been used in sheep at 500 mg/kg. Hexachlorethane was developed especially for use in cattles. Other drugs used are emetine hydrochloride, filcin, tetrachloroethane, etc.

Control. Control of liver flukes is effected in three major ways:

1. Snail control.
2. Treatment of infected sheeps.
3. Herd management through predicting out breaks of disease.

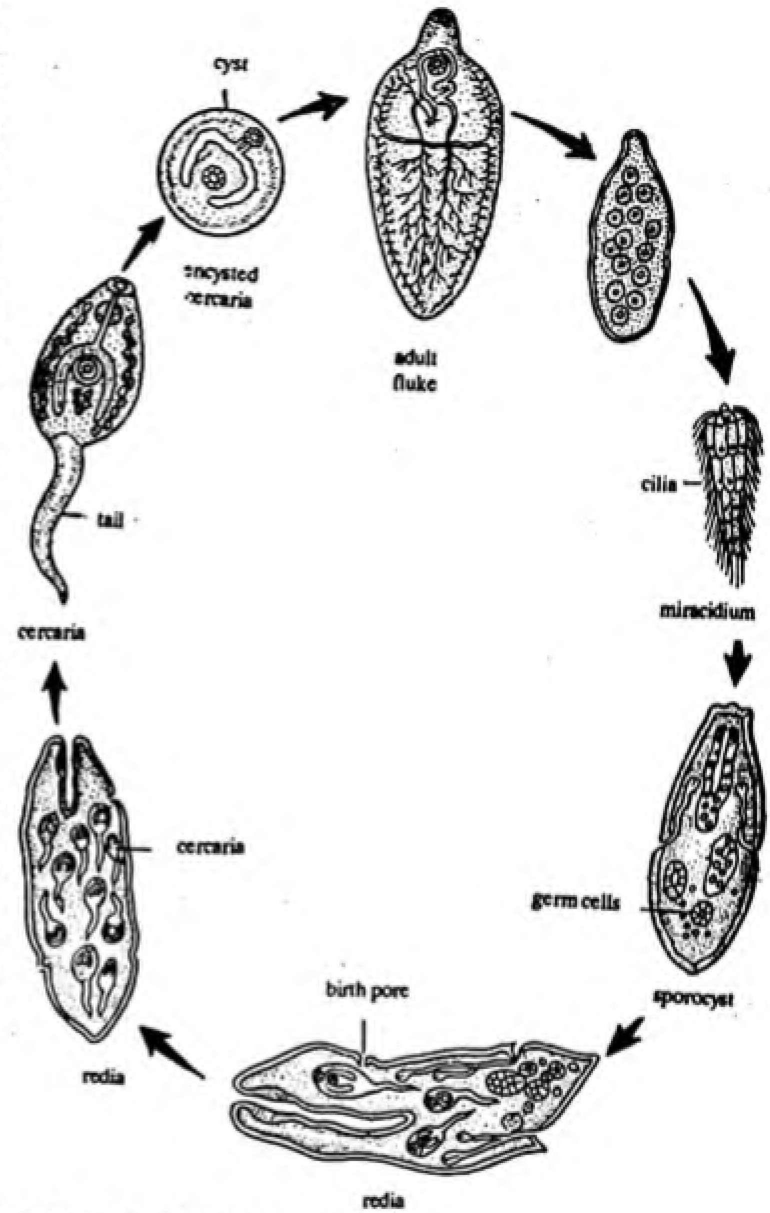

Fig. 32.21 *Fasciola*. Life-cycle.

Parasitic adaptions in *Fasciola*

The main changes that occur in the structure and life-cycle of a parasite, with the help of which it is capable of leading a parasitic life successfully, are called the *parasitic adaptations*. Since *Fasciola* is an endoparasite in the liver of sheep, it has undergone similar modifications under the stress of the parasitic mode of life which can be studied under two heads:

I. Structural modifications.

II. Modifications in the life-history.

I. Structural modifications

These modifications are of two types.

(A) Morphological

(B) Anatomical

(A) Morphological modifications

1. Body is dorsoventrally flatenned leaf-like and is nearly triangular due to which the danger of injury to its body is minimized.
2. Adhesive organs or suckers are present, an *oral* and a *ventral* or *acetabulum*. These are muscular and help in attaching to the tissue of host.
3. External features simple and is not divisible into head, trunk and tail. Appendages are also absent.

(B) Anatomical modifications

1. Body is devoid of cellular epidermis, thick cuticle is present to prevent the animal from the effect of chemicals from host body. Cilia absent in adult. Cuticle is provided with spinules for attachment.
2. The thickening of cuticle in the oral and ventral regions leads to the formation of two suckers.
3. The locomotary organs are lacking except in free living larval stages as adult *Fasciola* is an endoparasitic and it need not make excursions for food and safety.
4. The digestive system is incomplete. The *mouth* is anterior and terminal and surrounded by oral sucker. The pharynx is also muscular and sectorial. Both are adapted to suck the nutrient.
5. Intestine is highly branched so that digested food can be distributed to different parts of body. Anus is absent.
6. Circulatory and respiratory systems are absent. Anaerobic respiration takes place.
7. Excretory system is well developed. It consists of extremely branched excretory canals which terminate into flame cells.
8. Nervous system is poorly developed. Sense organs are absent.
9. Reproductive organs are extensively developed. The highly branched ovary and tests are capable of producing large number of gametes. Bisexuality offers full changes of fertilization.

II. Modifications in life-history

1. The production of eggs in a very large number, about 10 million, due to which the threat of survival of parasite is removed.
2. Eggs are shelled and each is provided with an operculum.
3. A secondary host is present for the dispersal of species.
4. Multiplecation takes place by *paedogenesis* during larval stage.
5. Miracidia are free swimming larval stages because they have to search new hosts. The cercariae are encysted when out of the body of secondary host which ensures protection from external effects.

33

TAENIA SOLIUM

Lt

Taenia solium belongs to class Cestoda. The members of this class are commonly known as 'Tapeworms'. All are endoparasites in the alimentary canal and associated ducts of various vertebrate hosts. During their life cycles one or two or more intermediate hosts, vertebrate and invertebrate, are required in which the tapeworms undergo a phase of development. The cestodes differ, however, from the members of other two classes (Turbellaria and Trematoda) in the complete absence of a digestive tract.

The present text mainly related to *Taenia solium*, the pork-tapeworm of man.

SYSTEMATIC POSITION

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Cyclophyllidea
Genus	-	*Taenia*
Species	-	*solium*

HABITS AND HABITAT

Taena solium or pork tapeworm is commonly found in those parts of the world where pork is eaten as food without properly cooking. It is found as an endoparasite in the gut of vertebrate hosts. One host is man and another is pig. Formerly, it was very common intestinal parasite in Europeans, especially in some places of Europe. It is rare in many parts of the world *viz.*, India, Philippines, North America. It is not at all found in Jewish and Mohammedan countries as in those countries eating of the flesh of pig is considered as an evil deed.

EXTERNAL MORPHOLOGY

Shape, size and colour. The body is elongate and flatenned dorsoventrally like a ribbon or tape. The body is narrow anteriorly and gradually broadens laterally towards posterior end.

The size of adult worm varies from 3-5 metres but a few are recorded to attain a length of about 8 metres.

The body is usually opaque white in colour but creamish, yellowish or greyish colouration is also common.

Division of body

The body of *Taenia* can be divided into three regions:

1. Scolex

2. Neck

3. Strobila

1. *Scolex.* The scolex is the holdfast organ, which is generally considered the anterior end. There are two schools of thought concerning the interpretation of the structure of tapeworms. Some consider a single scolex and connected proglottids to be a single animal. Others consider each proglottid to be an individual - hence, a single tapeworm is a colony of many individuals. Some helminthologists argue that the scolical end of the cestode is actually the posterior end. However, *Hyman* (1951) and *Chang* (1964) are not convinced with the argue that scolex is the posterior end. Furthermore, the more recent literature indicates the scolocal end should be considered the anterior end.

Scolex is a pear-shaped structure, but is four-sided at the posterior part. It possesses a small terminal cone called the *rosetellum.* Around the base of the terminal cone or rostellum is a double row of curved, pointed, chitinous hooks, which are usually 28 in number but are sometimes between 22 to 32. Hooks are of two types, long and small. They are arranged alternately. Long hooks are approximately of 180 μ and short ones are of 130 μ in dimension.

There are hooks.

Each hook consists of a *base* or *guard* by which it is fixed, a blunt projection or handle directed towards the apex and a conical outwardly directed *blade.* Rostellum is capable of slight protrusion and retraction. During protrusion hooks are directed forwards but when rostellum is retracted, hooks are directed backwards.

The mouth is absent in scolex. The term "head" frequently used for the scolex is, thus, inappropriate because the head is essentially that part of the body where organs for *perceiving* and catching food are aggregated. It measures about 0.6-1 mm in diameter.

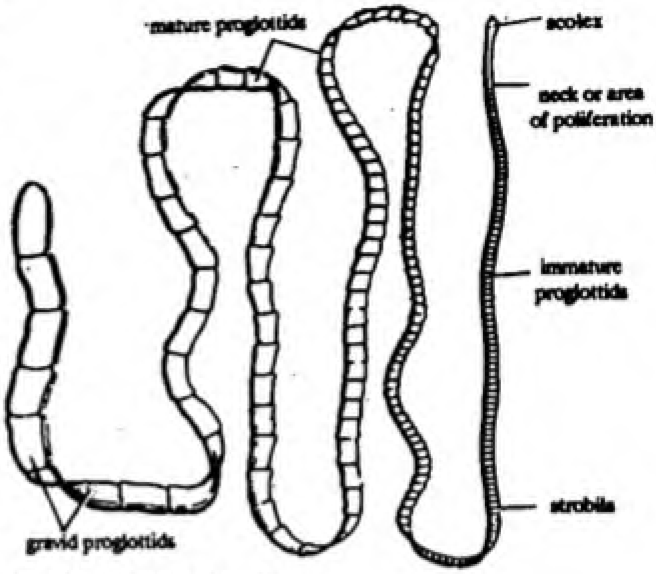

Fig. 33.1 *Taenia solium.* Entire.

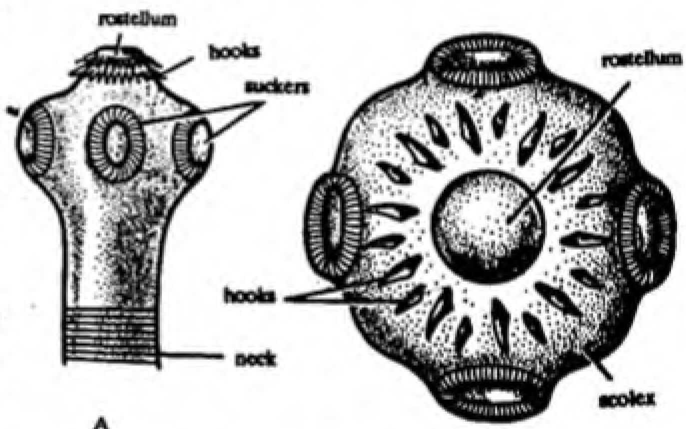

Fig. 33.2 *Taenia solium.* A—Scolex is magnified, B—Frontal view.

2. *Neck.* It is situated immediately posterior to the scolex. This is an unsegmented, poorly differentiated area that is generally narrower than the scolex and the strobila proper, and is the continuously differentiating or budding zone or area of proliferation that gives rise to immature proglottids.

3. *Strobila.* The strobila, which constitutes the main bulk of body and is made up of a chain of proglottids. There are about 800-1000 such *proglottids.* Each proglottid bears a complete set of genitalia. This linear repetition of genital organs is termed as *proglottisation.* Since the proglottids are budded off from the neck region in an orderly succession, the youngest proglottids are towards the neck and the oldest proglottids are posterior most.

Depending upon the development of genital organs, the proglottids are distinguished into three types:-

(i) *Immature proglottids.* These are young undifferentiated proglottids next to the neck region. The reproductive organs are either absent or in stages of development. Their width is more than the length. They comprise about 200 anterior proglottids.

(ii) *Mature or reproductive proglottids.* The mature proglottids are sexually mature consisting of a male and a female set of reproductive organs. They are usually as long as broad and are found in the middle of the body. They comprise about 450 proglottids. *Taenia* is protandrous, about 100 or 150 anterior mature proglottids contain only male reproductive organs and

remaining 300-350 contain both, male and female reproductive organs.

A mature proglottid is a complete reproductive unit in its own right and may underago self or cross fertilization.

(iii) *Gravid or ripe proglottid.* These are found in the posterior part of the body. These are characterised by the possession of a large, highly branched uterus filled with developing embryos. The rest of the genital organs have already disappeared from them after performing their function. They are longer than broad. The posterior most proglottids are cut off from the body and are expelled out of host body along with its faeces. This process of separation of proglottids is known as *apolysis.*

BODY WALL

The body wall of cestodes is made up of several layers but lacks a cellular epidermis. It consists of (i) cuticle (ii) Basement membrane and (iii) Musculature.

(i) ***Cuticle.*** The outer most layer of the body surface is called the cuticle or tegument. This layer is more or less transparent, noncellular, and without visible pores. The cuticle consists of two layers. (a) outermost hair-like or fringe-like *comidial layer* and (b) a thick *homogenous* layer. The cuticle is secreted by modified mesenchymel cells. These cells lie beneath the musculature and have long processes extanding up to the cuticle.

When studied under electron microscope, minute projections known as *microtriches* are present on the cuticular surface. *Rothman* (1963) suggested that the distal portion of each microthrix, which is solid, is concerned with two functions (a) it may serve as a means of resisting the intestinal current, since the body surface always in contact with the microvilli of the straited border of the cell lining of small intestine of host (b) it may serve to agitate the microhabitat in the vicinity as the worm moves, thus stirring up the intestinal fluids so that nutrient materials as well as waste products are always in a state of flux. The proximal position of microthrix is medullated and could very well serve as sites of absorption. In addition to microtriches, ultramicroscopic pore canals that communicate with the parenchyma are present in cuticle. These may be the sites of absorption also. Mitochondria and endoplasmic canals are also reported in the cuticle. Thus, it is apparent that this outer body layer is a dynamic structure rather than a mere covering.

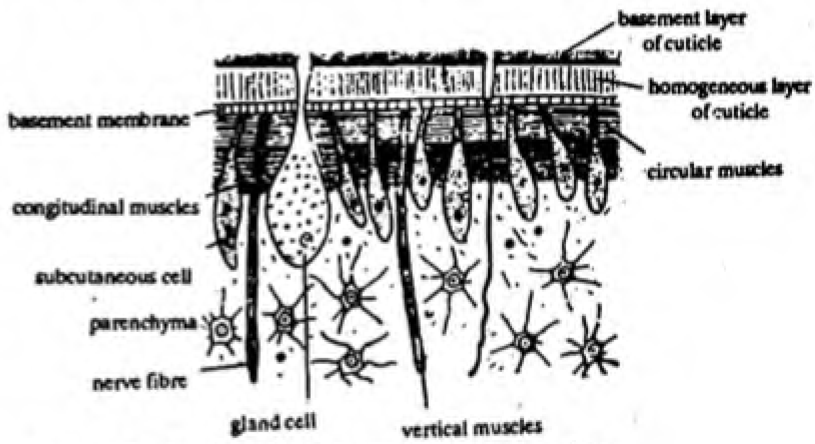

Fig. 33.3 *Taenia solium.* V.L.S. body wall seen under light microscope.

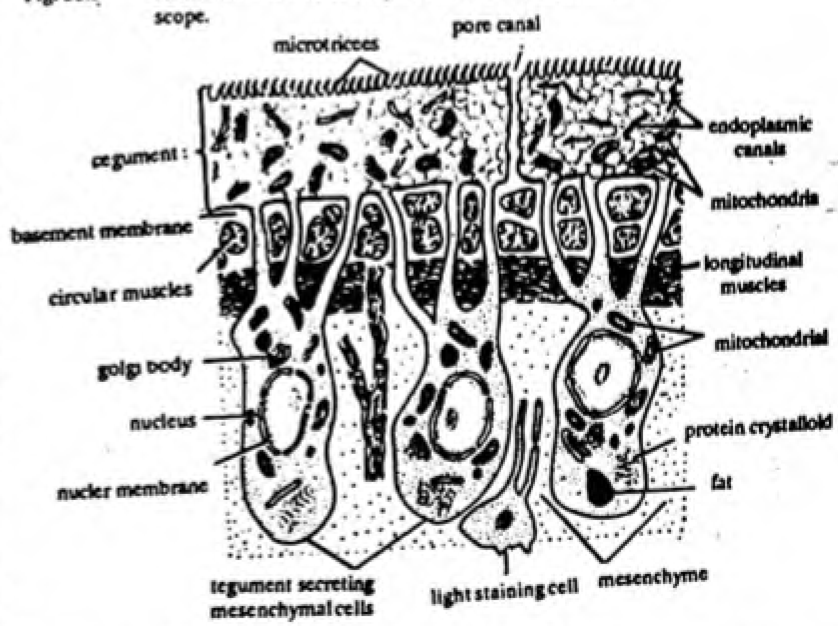

Fig. 33.4 *Taenia solium.* V.L.S. Body wall seen under electron microscope.

(ii) ***Basement membrane.*** Immediately beneath the cuticle is the basement membrane. This noncellular connective tissue layer contains vacuoles and granules. The protoplasmic layer beneath the basement layer is thick.

(iii) ***Musculature.*** Immediately beneath the basement membrane is a layer of *circular muscles* followed by *longitudinal muscles* and *vertical* or *dorsoventral museles.*

Mesenchyma or parenchyma

The space enclosed by the body wall, except for the occupied by the reproductive organs, osmoreguletroy structures, muscle fibres and nervous tissue, is filled with a spongy type of tissue, the parenchyma. Certain syncytially arranged cells form a network. In living animals, the space between the cells are filled with fluid. Numerous rounded calcarious bodies composed of concentric layers of calcium carbonate are present in mesenchyma secreted by *lime cells.*

Except at the two sides in each segment the parenchyma is divided into (i) outer *cortical* part and (ii) inner *meduallary* part by circular muscle fibres of the mesenctymal musculature.

The parenchymal cells, and to some extent the spaces, serve as sites for the storage of glycogen.

Nutrition

In *Taenia* there is no alimentary canal and as it lives in the intestine of host, there is totally absence of alimentary canal in all the stages of its life-cycle.

Its chief source of nourishment is obtained from the intestine of host. These are amino acids, glucose, glycerol etc.

Chandler thought that tape-worm gets its sugar supply from digeated food-material of a host but *proteins* and *vitamins* are made available to the animal from the living tissue of the host by the secretion of the digestive enzymes, which effect the cells.

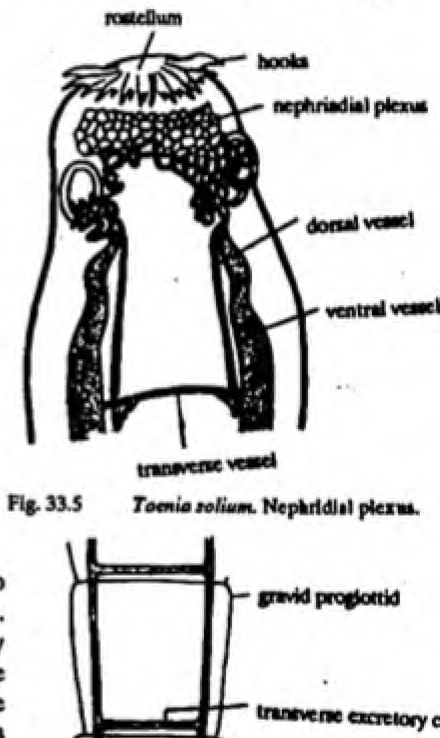

Fig. 33.5 *Taenia solium.* Nephridial plexus.

RESPIRATORY SYSTEM

In *Taenia*, the respiratory organs are absent so that respiration takes place through general body surface. Like other endoparasites, *Taenia* lives in the intestine of man where the oxygen content is very low or absent. So mode of respiration is anaerobic in which the energy is obtained by the break-down of glycogen into fatty acids and carbon dioxide. The carbon dioxide diffused out in surrounding medium. If oxygen is available, it respires aerobicaly.

EXCRETORY SYSTEM

Excretory system, also known as osmoregulatory system, is same as the protonephric type found in tremetodes.

Four main collecting canals traverse the entire length of the strobila. The two ventral canals are ventrolaterally located, and the two dorsal canals are dorsolateral. All these canals are situated in the peripharynageal zone of the meduallary parenchyma. A single transverse canal connects the two ventral canals at the posterior end of each proglottid. The ventral vessel carry the water away from the scolex, the dorsal vessels toward it. Within the scolex, the four longitudinal canals may be joined by a network of canals forming *nephridial plexus.*

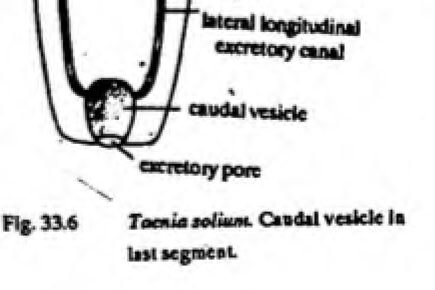

Fig. 33.6 *Taenia solium.* Caudal vesicle in last segment.

Along the length of ventral canals, a series of secondary tubules arise that may give rise to tertiary tubules. At the free end of terminal tubules are flame cells. The flame cells are generally arranged in a group of four. A flame cell is of irregular shape, with granular cytoplasm and nucleus. The 'flame' is actually a group of cilia that arise from a concave basal plate located near the cell nucleus. The cilia are enveloped in the funnel-shapted enlargement of the free end of the tubule. Waste products collected through the flame cells are passed down the tubules into the main

canals.

In the young worm, there is an *excretory vesicle* in the posterior most proglottid, into which the ventral canals open. However, as the neck region produces more proglottids, the older proglottids are pushed further back, and eventually the proglottid containing excretory vesicle is detached by the process of apolisis. Thus, in most older animal the posterior end of the tubes open independently to the exterior.

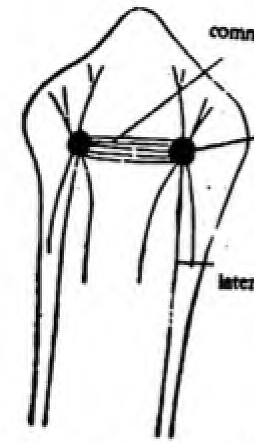

Fig. 33.7 *Taenia solium*. Nervous system.

NERVOUS SYSTEM

A thick band in the scolex with two ganglia constitute the brain or central nervous system. From the brain few nerves are given out anteriorly which innervate the scolex. Three pairs of longer nerves are given out towards the posterior region. Out of these only one pair, the *lateral nerve, cords* extend through the strobila passing just outside the excretory canal in each proglottid.

Sense organs are neither present nor they are necessary. Free nerve-endings are found in the body wall and detached proglottids for some time show independent muscular movement.

REPRODUCTIVE SYSTEM

Taemia is a *hermaphrodite*. Reproductive organs are usually found in the proglottids after 200th partitions. Some anterior proglottids are functionally male. Middle proglottids are both male as well as female. Proglottids at the posterior end are filled with enlarged *uterus*.

Structure of the proglottids in the middle region is as follows:-

I. The male reproductive system consist of the following organs:

1. Testes
2. Efferent ducts
3. Vas deferens
4. Cirrus or penis
5. Cirrus sac.

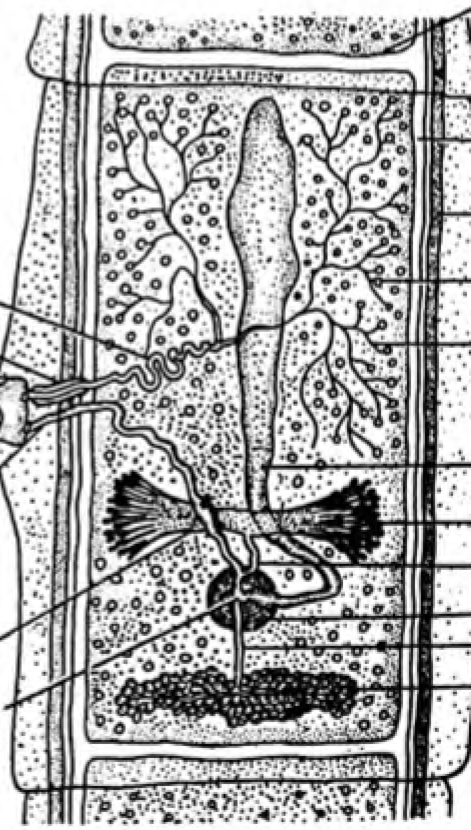

Fig. 33.8 *Taenia solium*. Mature proglottid showing reproductive system.

1. *Testes.* They are numerous small, rounded bodies situated in the medually part of the parenchyma. There number is about 15-200 and are distributed throughout close to the dorsal surface of the proglottid. Some workers are of the opinion that the numerous rounded follicle, in fact, constitute a single and highly sub-divided testis. However, the number of testes is of taxanomic value in tapeworms.

2. *Efferent ducts.* From each testis arises a fine ductule or capillary known as *vas efferens.* All the *vasa efferentia* unite to form a *vas deferens.*

3. *Vas deferens.* It is a long tube, arrising from the mid-part of the proglottid. It runs transversely to the left or right to open into cirrus. In some cestodes the vas deferens enlarges to form the seminal vesicle for the storage of sperms. But in *Taenia* no such enlargement is seen.

4. *Cirrus or penis.* The distal end of vas deferens in modified into a protrusible *cirrus.* The cirrus is armed with bristles, hooks or spines. It is eversible through male genital pore into a cup like *genital atrium* of the genital papilla.

5. *Cirrus sac.* Cirrus is surrounded by a kind of muscular sac known as cirrus sac. Its function is to erect penis during copulation.

II. The female reproductive system comprises:

1. Ovary
2. Oviduct
3. Ootype
4. Uterus
5. Vagina
6. Vitelline gland
7. Mehli's gland

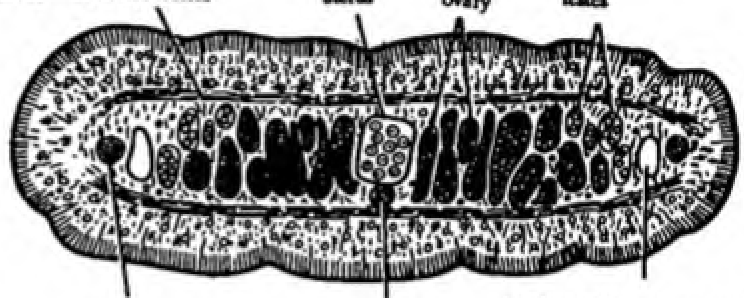

Fig. 33.9 *Taenia solium.* Diagrammatic T.S. of a mature proglottid.

1. *Ovary.* A single bilobed ovary lies ventrally in the posterior part of the proglottid. Each lobe of ovary is dorzoventrally flatenned and consists of a number of radially-arranged follicles. The right and left lobes are connected medially by a tranaverse bridge, the *ovarian isthmus*.

2. *Oviduct.* The oviduct arises from the middle of the bridge. It is a short but wide and joins the ootype distally.

3. *Ootype.* It is a small rounded chamber developed at the junction of oviduct with the vitelline duct. It is surrounded by numerous unicellular *Mehli's glands*, the cells of which form an amorphous complex.

4. *Uterus.* A blind sac-like or tube-like uterus arises from the ootype and runs forward in the segment. In gravid proglottids the uterus enlarges and gets branched to occupy the whole of the proglottid. It remains filled with the fertilized ova or developing embryos.

5. *Vagina.* The narrow tubular vagina arises from the receptaculum seminis and runs obliquely outwards to open into the genital chamber by female reproductive opening.

The seminal receptacle or receptaculum seminis is a small wide tube connected on one hand with the ootype by a narrow *spermatic duct* and on the other with vagina.

6. *Vitelline gland.* The vitelline gland is a compact, elliptical mass of numerous follicles situated posterior to the ovaries. A single short median duct, *median vitelline duct* arise from the gland and opens into the ootype. The secretion of the vitelline duct is rich in yolk and forms a covering of yolk and shall around the fertilized egg.

7. *Mehlis glands.* These are numerous minute unicellular glands situated around the ootype and emptying into it. The function of the secretion of Mehli's gland is to ease the passage of shelled eggs into the uterus.

LIFE CYCLE

Fertilization. Fertilization occurs by introducing the cirrus into the vagina of the same proglottid and sperms are stored in the receptaculum seminis, which later on fuse with eggs in uterus. Thus in *Taenia* self-fertilization takes place. Sometimes, the

anterior mature proglottids, devoid of female genitalia, can enter into copulation only with the posterior mature proglottids with fully developed female genital organs. Fertilization, following copulation between two different proglottids, is sometimes termed *cross-fertilization* to distinguish it from that occurring between gametes of the same proglottid (self-fertilization).

Thus the eggs are fertilized in the oviduct and get surrounded with yolk and egg-shall in the ootype. These materials are provided by vitelline gland. The capsulated eggs enter the uterus and are collected there. The uterus enlarges in size, gets branched and occupies the whole space. The eggs are small measuring 40 μ (micron) in diameter.

Cleavage. The zygote or egg cell undergoes cleavage when the capsule is in the uterus. The first unequal division results in a larger *megamere* and a smaller *embryonic cell.* The megamere divides further and froms several similar megameres, while the embyoonic cell divides repeatedly producing two types of embryonic cells, larger *mesomeres* and smaller *micromeres.* Thus, three types of cells result from the zygote; small micromeres, medium mesomeres and large megameres.

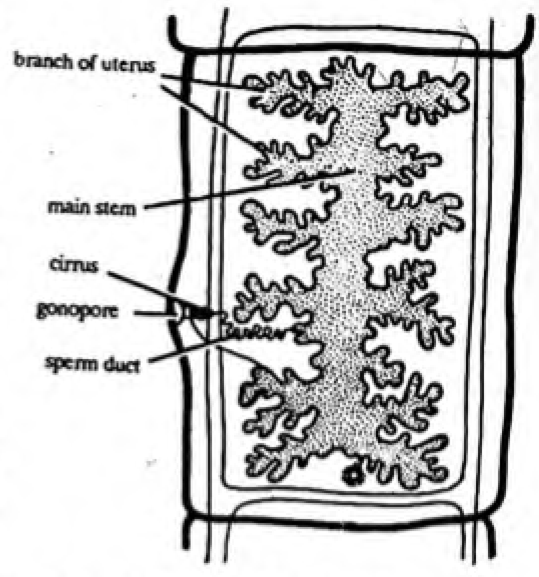

Fig. 33.10 *Taenia solium.* A gravid proglottid.

Onchosphere. By repeated division of micromeres a solid ball of cells, the *morula* is formed. The megameres divide, redivide and become filled up with yolk from the yolk cells, which surrounded the embryonic cells just like an envelope. It provides nourishment to the embryonic cells and finally disentigrates. The mesomeres form the inner thick striated membrane known as *embryophore.* Beneath embryophore lies basement membrane. The morula, develops three pairs of chitinous hooks. These *hooks* are secreted by the differentiated cells known as *onchoblasts.* Now the six-hooked embryo is called *hexacanth.* It possesses a pair of large penetration glands and is surrounded by two membranes, the hexacanth membranes. The hexacanth, together with all the membranes surrounding it is known as *onchosphere.* The onchosphere loses the shell.

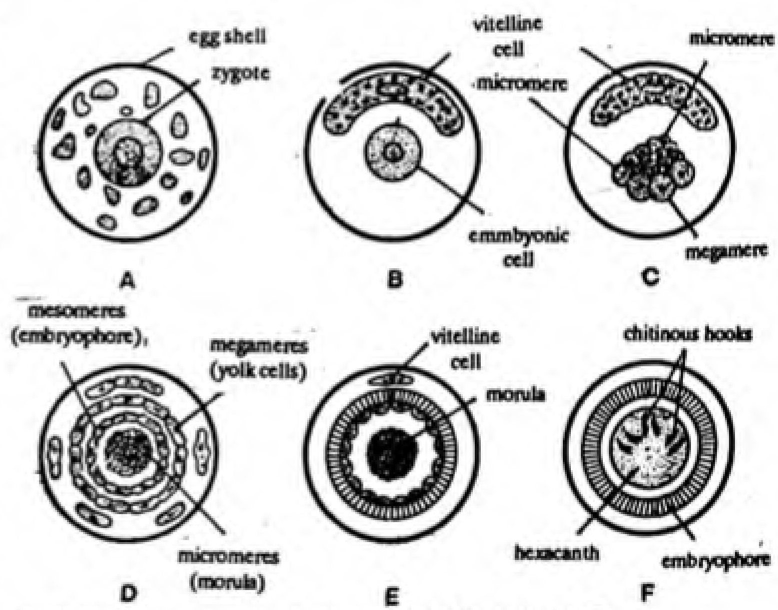

Fig. 33.11 *Taenia solium.* A—Zygote, B,C,D,E—Cleavage, F—Onchosphere.

These stages of development are found in the proglottids at the extreme posterior end of the body. The terminal proglottids are liberated from the body 4 or 5 at a time and are passed out quietly with the faeces of man. The proglottids show slow movements of contraction and later on perish. *Embryos* remain active for a considerable time. They are capable of further development only if they are taken in by a secondary host, which is a pig.

Infection to secondary host. The pig is the secondary host which regularly feeds of the faeces of man. Dogs, monke[illegible] and sheeps are also known to get infection.

Inside the alimentary canal of a pig, proglottids and thousands of egg's shells, nearly 30,000 to 40,000, are digested and *hexacanths* are set free. Later on, hexacanths bore their way with the help of hooks and penetration glands, through the wall of the intestine and reach intestinal blood vessels. The process requires only 10 minutes.

Migration. Travelling through the heart, these enter the muscles of various parts in the body. The usual site where the

hexacanths get encysted are the voluntary muscles of tongue, heart, liver and shoulder.

In the muscles, hexacanths lose their hooks, grow in size and develop a fluid-filled cavity in them. They now encyst in a cuticular covering. The encysted larvae are called *cysticerci* or the *bladder worms*. They are oval somewhat whitish in colour and measuring 6 mm x 10 mm. Their wall consists of cuticle and mesenchyme layer. The fluid within them is mainly the blood plasma of the host.

The side of the bladder opposite to the originally occupied by the hooks thickness and invaginates into the cavity.

The invagination, which looks like a hollow knob, differentiates into an inverted scolex or the *proscolex*, possessing suckers, hooks and rostellum. The embryo, at this stage, is called *bladder-worm*. In *T. solium* the bladderworm is of *cysticercus* type which is characterised by a large vesicle and one scolex. That is why the bladder-worm is also referred to as cycticercus. It appears to have a wall of cellulose and is, for this reason, sometimes called *cysticercus cellulosae*. Formation of cysticerci is completed in about 10 weeks in the pig. The cysticercus with proscolex is infective and waits for its ingestion by man.

The cysticerci remain alive and infective in muscles for 5-6 years before they die, and are than calcified by the host. There may be 500-3000 cysticerci in one kilogram of infective pork (pig's flesh). The infected pork has brownish spots and is called the *measly pork*.

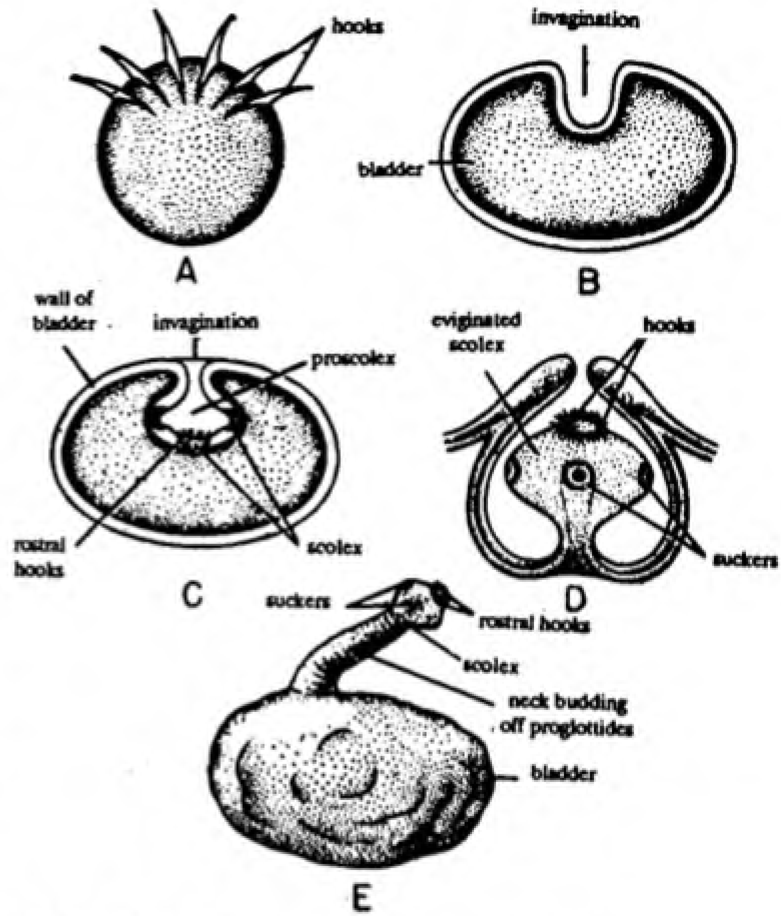

Fig. 33.12 *Taenia solium*. A—Hexacanth, B—Bladder worm with invagination, C—Bladder with prozcolex, D—Bladder worm with evaginated scolex, E—Cysticercus.

Infection to primary host. If the bladderworm or cysticercus is eaten with the pork by man, the bladder is digested and the young scolex attaches itself to the wall of intestine by hooks and suckers. A region of proliferation of neck is formed, which develops progiottids of the adult tapeworm. While anchoring itself to the wall of small intestine in matures in two or three months.

Pathogenesis

Both aduts as well as cysticercus stages are harmful:

1. *Adult worms.* The scolex of adult worm remains embedded in the mucous lining of alimentary canal for the attachment. The injury of musoca may lead to bacterial infection. There may be abdominal discomfort, diarrhoea, frequent hunger pangs, nervousness, insomnia, nausea nad epileptic etc. These symptons are due to the presence of adult worm are collectively known as *Taeniasis.*

2. *Cysticercus larvae.* Sometimes, man may accidentally ingest eggs or proglottids with contaminated food. Serious effects may result from cycticercosis in humans. Although they may be found in almost any organ, cysticerci are commonly located in striated muscles, liver, eye and the central nervous system, where they most often are in the meninges and ventricles of brain (*Marquez-Monter*, 1971). In an aberrant from of *T. solium*, apparently found only in the central nervous system, a cysticercus has daughter cysticerci budding from the bladder wall and forming an invasive, proliferating parasite. This type of metacestode

is referred to as a *racemose cysticercus*. No viable scolices have been found in recemose cysticerci (*Beaver* and *Rolon*, 1981).

Living cysticerci usually elicit little inflammatory response. They damage the host by forming space - occupying leisons, that is, their growth puts pressure on the adjacent tissue and interfers with its function or causes necrosis due to reduced blood circulation. In the brain ventricle the organisms cause *hydroceplulus* because the cerebrospinal fluid cannot be properly severe inflammatory reactions.

Treatment

Niclosamide is the dr:g of choice for intestinal infections, it is highly effective and well tolerated. Carbon tetrachloride and oleoresin are also used as an anthelmintic. For removal of tapeworms, doses of 0.4 gm each of atabrin and acranil or 1 gm of hexylresorcinol with 2 g n of acacia may be given. Cysticercosis is best treated in human by surginal removal of cysts, when possible. If surgery is no possible memeridazol can be administered.

Epidemiology and control

Intestinal infections in humans are acquired by eating inadequately cooked pork. Pigs are infected by eating gravid proglottids passed with human faeces. Since a single proglottid may have hundreds of eggs, a pig may obtain a heavy infection throughout its body by eating only a few proglottids.

Following are the principal means of control:

1. Adequate cooking of food.
2. Freezing pork after slaughter and before it is marketed.
3. Sanitary disposal of human waste.
4. Meat inspection.
5. Prompt treatment of person found to be infected.
6. An educational program aimed at changing habits of personal hygiene so that person do not reinfect themselves or others they have contact with.

PARASITIC ADAPTATION IN *TAENIA*

Taenia is an endoparasite in the intestine of vertebrate hosts. It has undergone a number of structural modifications to adjust in its specific environment. The modifications due to parasitic mode of life can be discussed under following headings:

I. Structural

II. Physiological

III. Modifications in Life-cycle.

I. Structural modifications can be divided into:

(A) Change in external form

(B) Change in internal form

(A) ***Change in external form***

1. Body is dorso-ventrally flatenned and ribbon like.
2. Neck possess the power of forming new proglottids.
3. Scolex or the anterior end is modified into a hold fast for attachment for this purposes scolex bears suckers and spines.

(B) ***Change in internal organs***

1. Body wall in devoid of cellular epidermis and remains invested by a thick and resistant cuticle.
2. Alimentary canal is absent because the animal lives in intestine where digested food materials always available.
3. Excretory system consists of protonephridia which helps in osmoregulation.
4. Respiration anaerobically.
5. Sense organs are absent except tangoreceptors.
6. Highly developed reproductive system.

II. Physiological adaptations

1. It can resist host's digestive enzymes through some unknown mechanism, probably by the secretion of anti-enzymes.
2. It maintains an equilibrium with the osmotic pressure of host.
3. It stimulates the mucous membrane of the intestine of host to secrete a large amount of mucous that cover for further protection against host's digestive enzymes.
4. Power of anaerobic respiration enables it to live in the oxygen-free intestinal contents.
5. Long flatenned body provides large surface area for absorption of digested food of the host that is why the mouth and alimentary canal are absent.

III. Modifications in Life-cycle

1. To cover the risk of finding individuals of different sexes in one host the organism is bisexual and moreover, each segment is bisexual and self-fertilization occurs.
2. Each proglottid produces 30-40 thousand eggs.
3. A secondary host i.e. pig is introduced to ensure its dispersal from one primary host to another.

34

ECHINOCOCCUS GRANULOSUS

Echinococcus granulosus or the 'hydatid worm', primarily parasetizes members of the canine family. The larval stage, the *hydatid*, is normally a parasite of sheep, but almost any mammal will serve as a host. It is potentially dangerous to human beings, in whom it may give rise to a fatal metastasizing, cancer-like tumor.

SYSTEMATIC POSITION

Phylum	-	Platyhelminthes
Class	-	Cestoda
Subclass	-	Eucestoda
Order	-	Cyclophyllidea
Genus	-	*Echinococcus*
Species	-	*granulosus*

HISTORY AND HABITAT

The hydatid disease, which is applied for any tumor or swelling of a cystic feature caused by *Echinococcus*. *Redi* (1684) and *Tyson* (1691) who had reported actual animal nature of hydatid. But it was first discovered by *Goeze* (1782). Next *Hartmann* (1695) who found the adult in the intestine of dog.

Thus *Echinococcus* is generally found in the small intestine of dogs, wolfs, foxes and other carnivorous mammals. But larvae of this parasite develop into hydratid cysts mainly in human being and domestic individuals.

DISTRIBUTION

Echinococuus is cosmopolitan in distribution, especially in sheep and cattle-raising areas. It has been reported from Iceland, South Australia, Tasmania, New Zealand, southern South America, southern and northern Africa, southern and eastern Europe, Siberia, Mangolia, northern China, Japan, and the near East. In India, it has been reported from Punjab.

EXTERNAL FEATURES

Shape and Size. The adult of *E. granulosus* is typically cyclophyllidean (*Taenia*), but it differs from it in size. It measures from 2-8 mm. in length.

Division of body. The body is divisible into (i) Scolex (ii) Neck (iii) Strobila.

(i) ***Scolex.*** The scolex is anteriormost part of body measuring 500 μ in diameter. The scolex bears four cup-like muscular structures, the *suckers* for the attachment to the intestine of host. Anteriorly situated, rectractile *rostellum* is armed with a double row of 20-80 hooks. *Smyth* (1963) has reported the presence of a group of cells lying just beneath the anterior tip of the rostellum. These cells not only contain droplets but actually secrete small viscid droplets to the exterior. The function of this secretion is still immunological standpoint, acting as an antigenic agent.

(ii) ***Neck.*** The narrow part of the scolex, behind the suckers, forms the neck. It is the area of strobilization.

(iii) ***Strobila.*** The strobila consists of three or four proglottids.

(a) *First proglottid.* First proglottid is indistinct. It follows the neck and is slightly wider than the neck. It consists of a genital rudiment only in the form of dark patch of cells.

(b) *Second proglottid.* This proglottid is well distinct. It is much larger than the first proglottid. It contains a full compliment of taenioid-like male and female reproductive organs.

(c) *Third proglottid.* It is gravid proglottid and is comparatively bigger in length as well as width than the other proglottids. It contains a uterus filled with a large number of eggs.

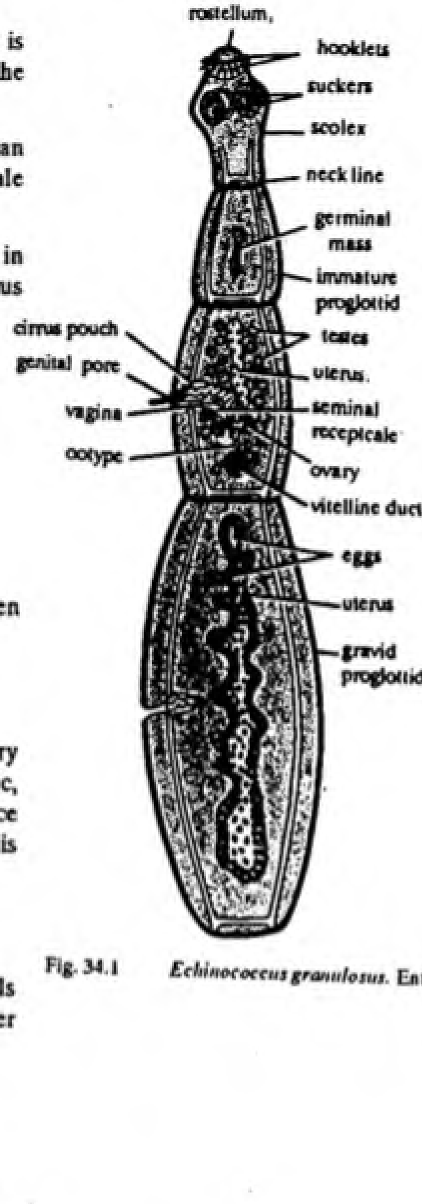

Fig. 34.1 *Echinococcus granulosus.* Entire.

INTERNAL STRUCTURE

BODY WALL

It is made up on the same pattern as in *Taenia*.

DIGESTIVE SYSTEM

The digestive system is absent. The predigested food of the host is taken through general body surface. The food is reserved in the form of glycogen.

RESPIRATORY SYSTEM

The respiratory organs are absent. The protoscolices of *Echinococcus* carry out aerobic fermentation of carbohydrates. The protoscolices excrete pyruvic, acetic, succinic and lactic acids, and small amount of ethyl alcohol. In the absence of oxygen there is an increased production of succinate and no pyruvate is excreted. Carbon dioxide which is formed as byproduct is diffused out.

EXCRETORY SYSTEM

It is well developed containing longitudinal and transverse excretory canals with flame cells. Excretory system mainly help in regulating the amount of water in body, hence they are mainly osmo-regulatory in function.

NERVOUS SYSTEM

Well concentrated in the scolex.

REPRODUCTIVE SYSTEM

Echinococcus is hermaphrodite. The male and female reproductive organs are present in the second proglottid or mature proglottid.

Male Reproductive System. In the middle region of proglottid, encircling the other reproductive organs, are about 20-30 spherical structure known as *testes.* From each testis a fine duct arises known as *vas efferens.* In the postmedial portion of the proglottid the vasa efferentia join to the base of a vas deferens. Vas deferens is an extremely convoluted, sperm filled tube, which passes lateral to an enlarged, coiled, marginal *cirrus* or penis. The cirrus lies in a bulbous *cirrus pouch* or *sac.* The cirrus, during copulation is protruded through a lateral *genital atrium* and genital pore.

Female Reproductive System. Opening into the genital atrium closely behind the cirrus is a female copulatory tube, the *vagina.* The vaginal opening is guarded by a muscular sphincter. Beyond the sphincter, the vagina passes downwards and enlarges at its inner end to form a sperm filled sac, the *seminal recepticle.* On the posterior side of the proglottid there is a bilobed *ovary*

with a narrow, central *isthmus* from which an oviduct arises posteriorly. The oviduct joins a duct from the seminal recepticle, and this combined fertilization duct continuous posteriorly into a median compact *ootype*. The ootype is surrounded by unicellular *Mehli's gland*. In the posterior most region there lies a bilobed *vitelline gland*. The two lobes of vitelline glands are oriented dorsoventrally. From the vitelline gland a median *vitelline duct* arises that joins the ootype. From the ootype a tube-like *uterus* arises which extends to a point near the anterior border of the proglottid.

Eggs. Eggs, resembling those of taenoid, are monoperculate and measuring about 30 x 38 μ. These are ectolecithal i.e. the zygote is surrounded by the yolk cells provided by vitelline gland and shall material. After an egg-shall is laid down the eggs pass from the ootype into the uterus. When the uterus of a gravid proglottid bursts, the eggs are liberated and passed out along with faeces of dogs. These eggs gain enterence into the intermediate host (man or other mammal) either through water or in forage. Each egg contains a fully developed *onchosphere*. Human infection develops from too intimate an association with dogs. Infection of children is commonly established when dogs are permitted to lick their mouths. Eggs can be ingested from contaminated fingers.

The eggs, upon being swallowed by a mammalian intermediate host, hatches in duodenum as a typical six-hooked onchosphere. The matching occurs in slight alkaline medium. Activation of embryos take place in either human bile or intestinal juice of ruminants, they are not activated in bile or intestinal juice of dogs and cats. The escaping onchospheres penetrate the intestinal wall, enter the mesenteric venules, and become lodged in the capillary beds of various organs. The hooks are now shed. After three hours of egestion, the embryo reaches its final place of development. Among mouse, deer etc. they reach lungs where as in man and other mammals, they reach in the liver, lungs, brain, kidneys, spleen etc. but liver being the most common site. Implantation and growth occur here, Onchosphere now develops into *hydatid cyst*. The cyst formation is a slow process, with the host laying down an envelope of connective tissue around the parasite. In about 4-5 months, the cyst reaches approximately 10 mm. in diameter. It goes on increasing in size and eventually becomes as big as the orange or even sometimes a football.

The various types of larval cysts, formed in the life-history of *Echinococcus* are:

1. *Unilocular hydatid cyst*. The hydatid cyst is composed of three layers. The inner most layer is called *endocyst*. It is thin syncytium forming the germinal layer. The middle layer is called *ectocyst*. It is made up of cuticle which is amorphous and laminated. The outer layer is *pericyst*. It is composed of connective tissue and fibres secreted by the host.

The cyst produces daughter cysts upon invagination of its wall. These daughter cysts project into the lumen of mother cyst. The cavities are filled with a sterile fluid known as *hydatid fluid*. Within some daughter cysts, tertiary or grand-daughter cysts, formed by invagination. These are endogenous or exogenous cysts or brood capsules.

The endogenous cysts fall free into the hydatid fluid of mother cyst while the exogenous cysts, after detaching, migrate to other part of body, where they continue to grow further. The daughter cysts have a fibrous cyst wall internally lined with endocyst.

Rounded and hollow brood capsules are also continuously budded off from the endocyst of mother cyst. These capsules remain attach for some times by means of a narrow pedicle.

From the wall of these brood capsules, minute scolices are formed. Scolex formation may occur from the invagination of walls either of daughter or grand-daughter cyst.

The anterior end is inturned to form a central canal into which the four suckers open and into the expanded base of which the hooklets project. The body of each scolex is filled mesenchymal calls aggregated to form

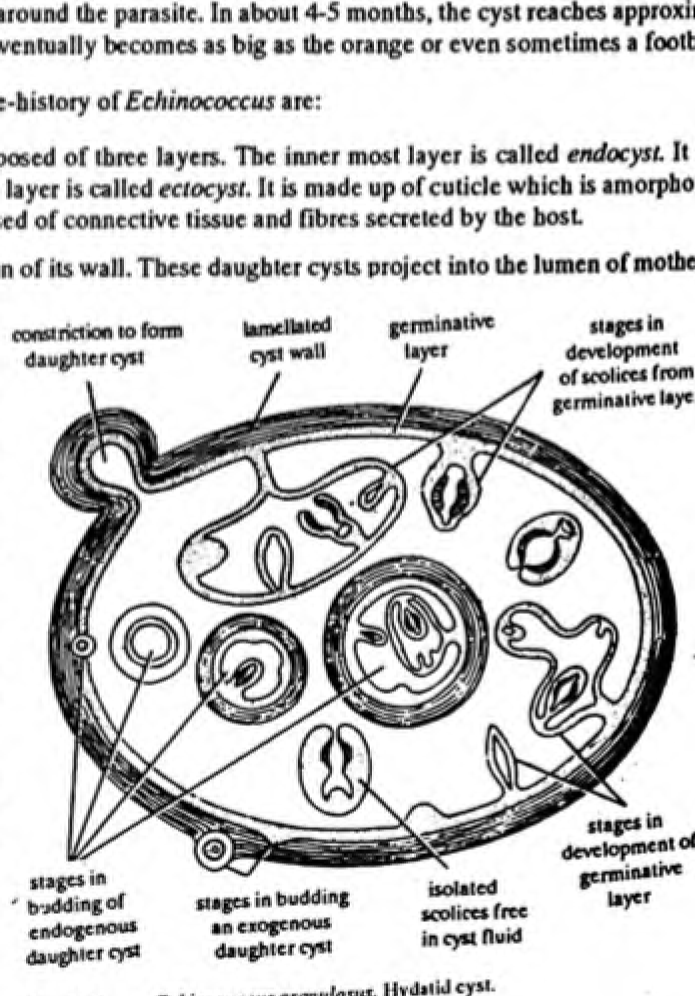

Fig. 34.2 *Echinococcus granulosus*. Hydatid cyst.

a subcuticular layer and to form a compact cup-shaped mass below the booklets. The syncytium of the endocyst retains its embryonic potentialities, and new brood capsules may be produced indefinitely. Hydatids thus may expand to enormous size and contains nearly 50 litres of fluid as well as thousands of scoleces. The pressure so produce may severely damage adjacent host organs.

When the infective brood capsule is ingested by the final host, each scolex quickly evaginate and attach to the duodenal mucosa. For the first four to five days in the host they undergo little growth. By the 14th day the scolex has grown in size, and first proglottid has appeared. The genital anlage and a second proglottid appear by the 18th day. Growth continues and fully developed shelled embryos are formed by about the 35th day, and the life cycle is begun again.

2. *Multilocular cyst.* It is characterized by many small bladders embedded in a common enclosing membrane. These are found in cattles. It is considered to be the result of differential reaction inside the host.
3. *Alveolar hydatid in man.* It is characterized by a malignant type of growth with jelly-filled proliferating vesicles embedded in a common dense stroma. The very thin laminated membrane does not restrict the germinal membrane that grows out into surrounding host tissues. It is commonly sterile and it undergoes degeneration and calcification.
4. *Multivesicular.* It is characterized by many adjoining and connected bladders, each having its own separate germinal membrane.

PATHOGENESIS

Bladders or cysts are harmful when they develop rapidly. It causes inflammatory reaction in the surrounding tissue of the host result in the formation of fibrous tissue. The escaping hydatic fluid not only causing diarrhoea, abdominal pain etc. but also death of the host sometimes.

TREATMENT

Surgery is the recommended treatment for hydatid disease, but removal of a hydatid cyst must be approached with care. An individual harboring a hydatid often develops hypersensitivity to the fluid in the cyst and if the cyst is broken during surgery and fluid leaks into the body cavity, the patient may die within minutes from anaphylatic shock. If the patient survives, protoscolices, which are liberated from breakage of cyst, may set up secondary infection. In order to check the secondary infection sometimes it is recommended to inject the cyst with alcohol or iodine to kill protoscoleces.

Mebendazol has been successfully used in some individuals who have hydatid in locations that are inoperable (*Keystone* and *Murdoch*, 1978). Adult worms in dogs are susceptible to treatment with praziquantel (*Wilson* and *Rausch*, 1980).

CONTROL

The followings are the elements of a control programme for hydatid disease:

1. Treatment of infected dogs with an effective anthelmintic or to kill them.
2. Keeping the viscera of domestic animals from being eaten by dogs.
3. Children should not be allowed to play dogs frequently.
4. Avoiding play with dogs and hands should be thoroughly washed before eating.

35

PHYLUM - ASCHELMINTHES

There is variety of opinions among zoologists about the systematic position of nematodes. Some authors (*Gagenbaur* etc.) have designated a separate phylum Nemathelminthes, which includes or not include Acanthocephale and Nematomorpha. Recently, nematodes have been grouped in a class Nematoda in the phylum Aschelminthes. The term Aschelminthes is coined by *Grobben*.

CHARACTERS

1. Round worms have elongated, cylindrical and vermiform body with tapering ends.
2. Body is unsegmented but may be wrinkled. It is not distinguished into regions.
3. Body unpigmented being either white or with a yellowish tinge.
4. Caudal end of the body generally straight in female but coiled in males and the males are shorter than females.
5. Anterior cephalization is not prominent, therefore, the body is without any definite regions.
6. Mouth terminal surrounded by lips. In strongyloides the lips are modified into teeth known as leaf-crown.
7. Amphids and papillae are the main sensory organs and are of great taxonomic value in case in free-living forms.
8. Marine nematodes are annulated due to the presence of transverse striations or longitudinal striations which are of common occurrence.
9. Body is covered by rough resistant cuticle, having bristles, spines warts and papillae etc. Sometimes cuticle modified as cephalic, cervical and lateral cuticle and in the form of vesicle.
10. Caudal end with a pouch of cuticular nature known as phasmids, very common in parasitic form.
11. Cuticle in the strongyloides is modified into an umbrella-like form known as bursa which is generally supported by muscular rays.
12. The layers of body wall generally made up of cuticle sub-cuticle or epidermis and muscle layer. The cuticle is generally of keratin which allows only glucose and urea etc.
13. Epidermis is syncytial where they are usually divided in four sections in the four longitudinal chords. One dorsal, one ventral and 2 lateral in position.
14. Muscles consist of longitudinal muscle fibres with variable arrangements which is generally holomyarian, meromyarian and polymyarian etc. The muscles are of great taxonomic value.
15. The body cavity is pseudocoel.
16. Digestive tract well developed generally made up of mouth, buccal cavity, pharynx or oesophagus are of various type, intestine and anus.
17. Nervous system consists of a nerve-ring encircling the oesophagus. From it nerves are given out anteriorly and posteriorly.
18. Protonephridia absent but the excretory system is made up of canals or gland-like organs.
19. Sexes are separate. Testes and ovaries are tubular and coiled. Usually there is a single testis. The ducts from the testes open

into the cloaca and the cloaca is associated with accessory structures such as circular spicules. Ovaries, oviduct and uteri are double.

20. Aschelminthes are ovo-viviparous, oviparous or viviparous.
21. Life-cycle complicated may be with or without intermediate host.
22. Larval stage four. Third stage of larva is infective.

CLASSIFICATION

Phylum Aschelminthes is divisible into one class-Nematoda.

CLASS - NEMATODA

1. Body is slender, cylindrical, tapering towards both the ends.
2. Body is covered with cuticle.
3. Intestine is well formed.
4. Body cavity is not lined with epithelium.
5. Cloaca is absent in female.
6. Male and female reproductive organs are well developed.

The Classification of Nematoda is not stable as they have been studied mainly independently. The scheme given below will be found simple and convenient.

Class Nematoda is divided into two sub-classes:

Sub-class I-Aphasmidea

Sub-class II-Phasmidea

Sub-Class I-Aphasmidea

1. Phasmids or caudal sensory organs are absent.
2. Amphids or anterior sensory organs many.
3. Excretory organs either reduced or absent.
4. Coelomocytes and mesenterial tissue are well developed.
5. Caudal alae in females are absent, free living.

The Sub-class is divided into following orders:

Order (1) Chromadoridea

1. Oesophagus is not elongated but differentiated into three regions.
2. Cuticle smooth or ringed. Ornamented and sometimes with bristles.
3. Amphids spiral.
4. Mainly marine and free-living.

Examples: *Druconematids, Walichoanolaimus.*

Order (2) Enoploidea

1. Mainly marine and free-living.

2. Six sensory papillae on the lip.
3. Ten to twelve sensory bristles arranged in one or two circlets.
4. Cyathiform (goblet-shaped) amphids.
5. A pair of cephalic slits.
6. Size small to moderate.

   Examples: *Pelagonema, Enoplus, Metonchidiamus.*

Order (3) Dorylaimoidea

1. Found in fresh-water and soil.
2. Cuticle smooth without bristles.
3. Head with an inner circlet of six and an outer circlet of ten sensory papillae.
4. Odontostylet, the piercing apparatus derived from a modified tooth in the oral region.
5. Amphids cyathiform.
6. Posterior part enlarged.

   Examples: *Dorylaimus, Xiphinema.*

Order (4) Mermithoidea

1. Anterior end with 16 labial papillae.
2. Sensory bristle absent.
3. Cuticle is smooth.
4. Amphids either rudimentary or cyathiform.
5. Oesophagus opening in blind intestine.
6. Larvae parasites in invertebrates whereas adults are free living.

   Examples: *Mermis, Paramermis.*

Order (5) Trichuroidea

1. Intestinal muscles, caudal gland or suckers are absent.
2. Mouth without lips.
3. Pharynx very long and narrow.
4. Females with one ovary.
5. Males with one or no copulatory spicule.

   Examples: *Trichinella, Trichuris.*

Order (6) Desmocolecoidea

1. Small sized with heavily ringed cuticle.
2. The head is armoured. Anterior end with four sensory bristles.
3. Amphids are crescent shaped or pump-shaped.
4. They are marine and free-living.

Examples: *Tricoma, Desmoscolex.*

Order (7) Monohysteroidea

1. Small forms with smooth or ringed cuticle having bristles.
2. Amphid circular.
3. Anterior end with 4, 6, 8, or many sensory bristles.
4. Free living forms, few are marine, some are fresh water and others terrestrial.

   Examples: *Monohystera, Siphonolaimus.*

Sub-class II - Phasmida

1. With phasmids and pore like amphids.
2. Excretory organs with paired lateral canals.
3. Coelomocytes 4-6.
4. Caudal or hypodermal glands absent.
5. Reproductive system well developed.

   The sub-class has been divided into following orders:

Order (1) Rhabditoidea

1. Mouth without lips and with 6, 12, or 18 papillae.
2. Cuticle is ringed or smooth.
3. Pharynx, long with posterior bulb.
4. Single ovary in females and males with copulatory spicules.
5. Mostly parasite on birds and mammals.

   Examples: *Rhabditis, Diplogaster.*

Order (2) Oxyuroidea

1. Pinshaped small or medium sized.
2. Cervical papillae absent.
3. Pharynx with posterior bulb.
4. Females with slender tail.
5. Males with one or two copulatory vesicles and sometimes with alae forming a bursa.
6. Parasites in invertebrates and vertebrates.

   Examples: *Enterobius, Oxyuris.*

Order (3) Ascaroidea

1. Large parasitic.
2. Mouth surrounded by three rarely six lips.
3. Cervical papillae present.
4. Pharynx with or without valve.

5. Female short tail.
6. Male with ventrally coiled tail and with two equal copulatory spicules and usually without alae.

   Example: *Ascaris.*

Order (4) Strongyloidea

1. Mouth without distinct lips but has leaf crowns.
2. Pharynx is without bulb.
3. Males are provided with a distinct caudal bursa which is supported with rays.
4. Females with a ovejactor.

   Examples: *Ancylostoma, Necator, Strongylus.*

Order (5) Dracunculoidea

1. There are no definite lips or buccal capsule.
2. Mouth is surrounded by ring of papillae.
3. Pharyngeal bulb is absent. Pharynx is muscular anteriorly but glandular posteriorly.
4. Copulatory bursa is absent in males.
5. They are parasite of vertebrates.

   Examples: *Dracunculus, Micsopleura.*

Order (6) Spiruroidea

1. Mouth with two lateral lips, sometimes 4 or 6.
2. Pharynx with bulb with anterior muscular and posterior glandular part.
3. Males without bursa but have spirally coiled tail.
4. Parasitic forms.

   Examples: *Gnathostoma, Spiroxys.*

Order (7) Rhabdiasoidea

1. Cuticle smooth.
2. Definite pharyngeal bulb is absent.
3. Parasitic stage is hermaphrodite or parthenogenetic free-living stage may develop into males and females.

   Example: *Rhabdias.*

Order (8) Filariodea

1. Slender filiform worms.
2. Mouth simple, lips are absent.
3. Females larger having an anterior vulva and a long tubular vagina.
4. Males with two unequal spicules. Alae present or absent.
5. Found in blood or lymphatic system. Transmitted by blood sucking insects.

   Examples: *Wuchereria, Microfilaria, Loa.*

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TRICHURIS

Phylum	-	Aschelminthes
Class	-	Nematoda
Sub-class	-	Aphasmidea
Order	-	Trichuroidea
Genus	-	*Trichuris*

1. It is commonly called as *whip-worm.* It is an endoparasite found in the caecum and large intestine of man.
2. It has world wide distribution but common in tropical countries.
3. Female is slightly larger than males.
4. The anterior part of the body having pharynx is usually more slender and this portion is buried in the mucosa of host's alimentary canal.
5. Mouth is simple without lips.
6. It feeds on blood and epithelial cells.
7. Life-cycle is simple with no intermediate host.
8. Development of eggs take place in moist soil. Embryos develop in about three weeks.

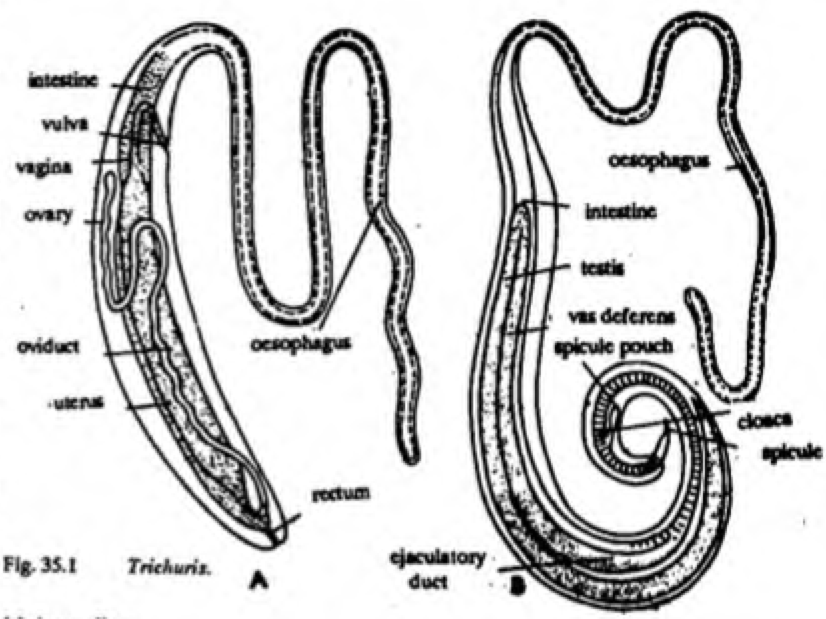


Fig. 35.1 *Trichuris.*

9. Contaminated food and water responsible for infection in man by swallowing eggs with juveniles.
10. Liberated juvenile grow into adults within a mouth.
11. Excretory system is absent.
12. Heavy infections is responsible for diarrhoea and anaemia.

TRICHINELLA

The systematic position is the same as that of *Trichuris.*

1. It is a parasite of man, pig, rat and other vertebrates. It is commonly known as *trichinia worm.*
2. It is commonly found in Europe. United States and Arctic regions.
3. Sexes are separate, males are about 1.5 mm. in length and the females are 3 mm. in length.
4. In both the sexes, the mouth is without lips.
5. Pharynx is long, slender and non-muscular and is embedded in stichosome.
6. The oesophagus is tubular, well developed and occupies 1/3 of the total length of body.
7. The female worms which are viviparous enter the lymphatic reaches the muscular system where they secrete a cyst around them. This is called encysted sexless stage.
8. The encyated sexless trichinae are ingested by man along with pork-flesh, where the cyst wall is dissolved by the action of digestive juice and the reproductive organs start developing.

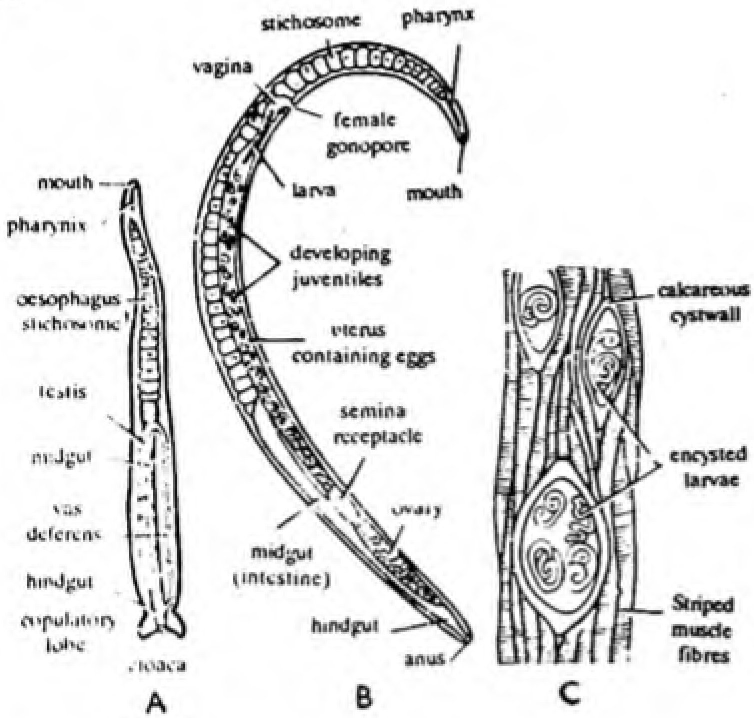


Fig. 35.2 *Trichinella*. A—Adult male, B—Adult female, C—Encysted larvae in striped (voluntary) muscle of pig.

9. The developing worm begins to migrate into the muscl and produces the symptoms of a dreaded disease call . *Trichinosis.*

10. Patients feel gastro-intestinal pain, and weakness with or without fever.

RHABDITIS

Phylum	-	Aschelminthes
Class	-	Nematoda
Sub-class	-	Phasmidea
Order	-	Rhabditoidea
Genus	-	*Rhabditis*

1. Genus *Rhabiditis* includes numerous free-living, semi-parasitic forms. They are commonly found in organic matter, faeces of man. They feed on the fluid formed by bacterial decyin ; of organic matters.
2. The pharynx has two bulbs with an isthmus joining them.
3. The excretory system is H-shaped.
4. The reproductive system is J-shaped.
5. The large female ncs a pointed tail and didelphic sex-organs i.e. having paired ovaries, oviducts, seminal recapticles and uteri.

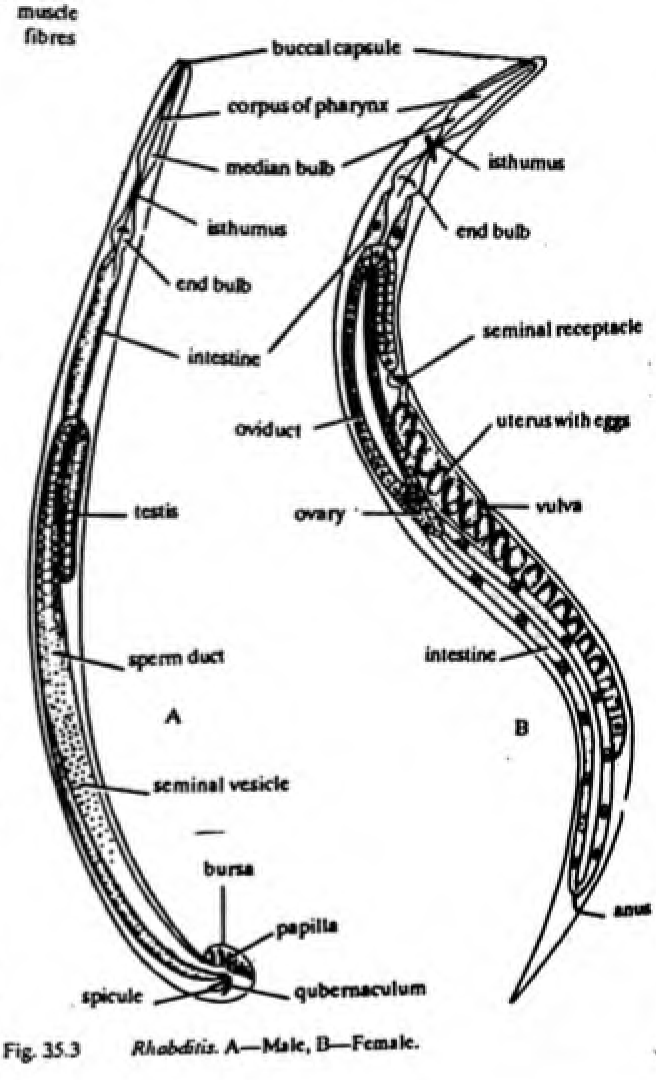


Fig. 35.3 *Rhabditis*. A—Male, B—Female.

6. The male has a flatenned copulatory bursa, two equal spicules and monorchic sex organs i.e. single testis.
7. Life-cycle is simple and direct. The juveniles adhere to the bodies of dung beetles for transport to fresh dung.

ENTEROBIUS VERMICULARIS

Phylum	-	Aschelminthes
Class	-	Nematoda
Sub-class	-	Phasmidea
Order	-	Oxyuroidea
Genus	-	*Enterobius*
Species	-	*vermicularis*

1. It is commonly called *'pinworm'* or *'seatworm'*.
2. It has world-wide distribution, but specially found in Europe, India, Africa, Canada, Chile and U.S.A.
3. Adult worms live in the caecum, appendix and adjacent parts of intestine of man.
4. Sexes are separate. The male measures 2-5 mm. in length and the female measures 8-13 mm. in length.
5. Anterior end is provided with three lips and a pair of cephalic expansion.
6. Male has a ventrally curved tail with a single spicule and a pair of cuticular expansions known as caudal alae. It is minorchic.
7. Female has a straight tail which becomes long and pointed. It is didelphic. Vulva is anterior.
8. Life-cycle is simple there is no intermediate host. Gravid females migrate to anus causing itching sensation. They crawl and deposit eggs on the perineal skin. Due to scratching, gravid females rupture and thus small eggs are liberated. The re-infection in children takes by putting fingers in mouth. Eggs hatch. Juveniles inhabit small intestine. They moult twice and turns into adults which reach their normal habitat. The infection is called *Enterobiasis*. Symptoms are inflammation of caecal mucosa, abdominal pain, insomnia, hysteria, restlessness, loss of appetite and sometimes appendicitis.

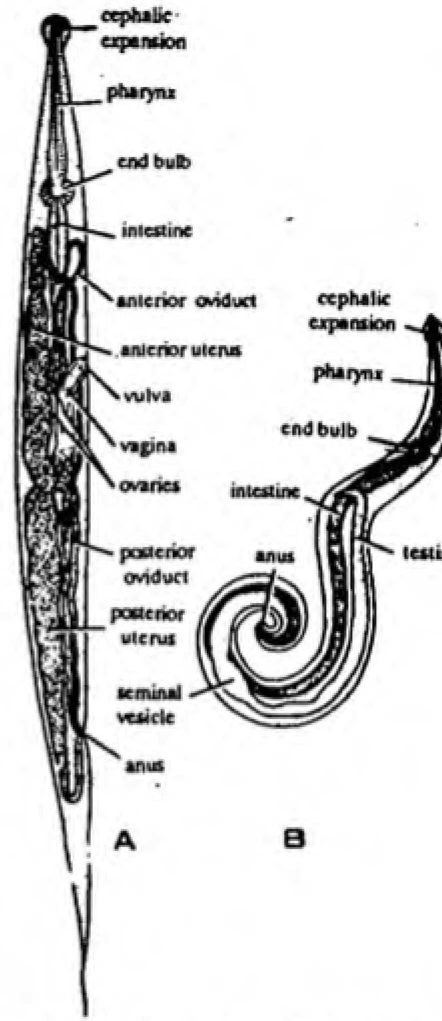


Fig. 35.4 *Entrobius*. A—Male, B—Fimale.

LOA LOA

Phylum	-	Aschelminthes
Class	-	Nematoda
Sub-class	-	Phasmidea
Order	-	Filarioidea
Genus	-	*Loa*
Species	-	*loa*

1. It is commonly known as *African eyeworm*, chiefly found in Africa.
2. They live in the subdermal connective tissue of man in West Africa.
3. The male and female measure 20-35 mm. and 20-70 mm. in length respectively.
4. Body is covered by numerous warts.

Fig. 35.5 *Loa loa* in the cornea of man.

5. The intermediate hosts are mango flies, *Chrysops*. The larvae moult and develop up to infective stage in fly. These are transmitted in blood of man through proboscis.
6. The adult worm moves about in the body in the subdermal tissue and sometimes passes across the eye ball causing intense itching and swelling known as 'calabar swellings'.
7. These are injurious and fatal when they penetrate brain and spinal cord.

DRACUNCULUS

Phylum	-	Aschelminthes
Class	-	Nematoda
Sub-class	-	Phasmidea
Order	-	Dracunculoidea
Genus	-	*Dracunculus*
Species	-	*medinensis*

1. It is commonly called '*Guinea Worm*'. It is found in tropical countries like India, Africa, South America and West Indies.
2. It lives in the deeper subcutaneous tissues of man.
3. The anterior end is blunt while the posterior end is pointed.
4. The adult male measures 4 cm. in length. It's hind end is curved and bears 10 pairs of genital papillae and a pair of pineal spicules.
5. Adult female measures 70-120 cm. in length. It's hind end is straight and bears a spine-like process.
6. The oesophagus is distinguished into an anterior narrow muscular region and a posterior broader glandular region.

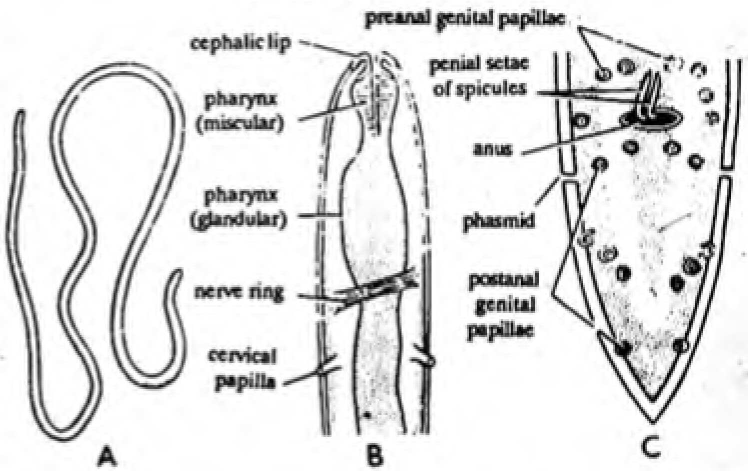


Fig. 35.6 *Dracunculus medinensis*. A—Entire, B—Anterior end of male, C—Posterior end of male in ventral view.

7. The female reproductive system is didelphic with opposed uteri.
8. Females are viviparous. The alimentary canal and vulva are atrophied in mature females.
9. Mature female migrates to the superficial layers of the skin in those parts of the body which are likely to come in contact with cold water. Toxic substances are produced under the skin which results in the formation of a blister, leading to an ulcer, which breaks on coming in contact with water. On coming in contact with water, the worm ruptures, releasing larvae in water. The larvae swims about but do not develop further unless swallowed by *Cyclops*, which serves as intermediate host. Here the larvae moult twice and become infective. Infection occurs when *Cyclops* are swallowed by a new host alongwith drinking water.
10. It causes *guinea worm disease* characterised by asthma, nausea, vomiting, diarrhoea etc.

36

ASCARIS LUMBRICOIDES

Much is known about the morphology and life-cycle of Nematoda but out of them *Ascaris* is most known. *A. lumbricoides* is the most common nematode parasite found in the human intestine. Being of large size and found abundantly, *Ascaris* is studied as the main example of the nematodes.

SYSTEMATIC POSITION

Phylum	-	Aschelminthes
Class	-	Nematoda
Sub-class	-	Phasmidea
Order	-	Ascaroidea
Genus	-	*Ascaris*
Species	-	*lumbricoides*

HABITS AND HABITAT

A. lumbricoides, a large nematode parasite of man, is world wide in distribution. It occurs more commonly in the small intestine of children than in adults because of the children's custom of playing in contaminated, egg-laden soil adjacent to dwellings. As many as 1000 - 1500 adult worms may be present in a single host. Because of their strong, pointed and cuticulate bodies and their habit of wandering, they may perforate the gut wall and cause peritonitis or they may enter the bile or pancreatic ducts or the vermiform appendix and interfere with normal digestive functions.

EXTERNAL FEATURES

Shape and Size. Both the sexes are elongated, cylindrical and pointed at both the ends. Males are 15-31 cm. long and 2-4 mm. in diameters, while the females are 20-35 cm. long and 4-6 mm. in width. The males are further distinguished by a ventrally curved posterior end, from the slit-like opening of which often protrude two copulatory spicules.

Colouration. In the living condition, the colour of the animal is milky-white or reddish-yellow. There is a characteristic lustre on the body.

Longitudinal lines. There are four longitudinal lines or streaks, running throughout the length. One is mid-dorsal, one mid-ventral and two lateral. The dorsal and ventral lines are white in colour, the lateral streaks are thicker and broader than dorsal and ventral streaks and are brown in colour.

Mouth. A triangular mouth is present at the anterior end of the body. It is surrounded by three denticulated lips. One of these is mid-dorsal and other two are latero-ventral in position. The mid-dorsal lip is almost elliptical and has a

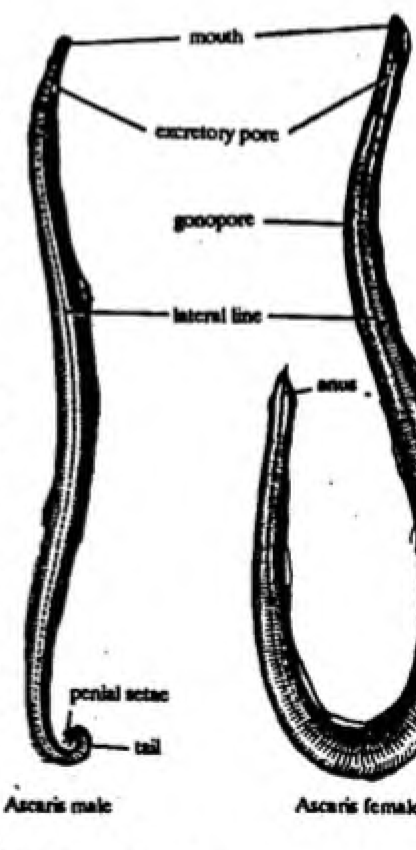


Fig. 36.1 *Ascaris lumbricoides*.

forked fleshy core in the centre. A circle of four *sensory papillae* is found on it. The remaining two lips also have a forked core and two rows of sensory papillae. Each sensory structure is called *amphids*. The sensory papillae of nematodes are very useful in the identification of the species and assigning their position in the classification. The sensory papillae are *tangoreceptors*. The amphids are *chaemoreceptors*.

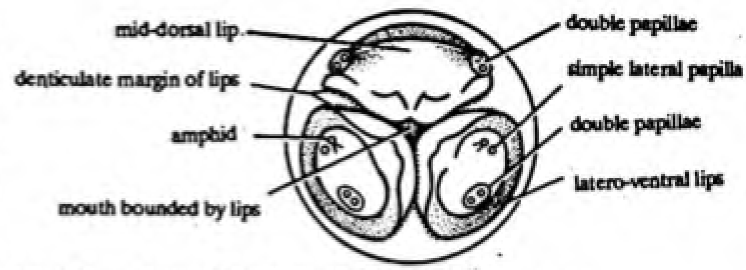


Fig. 36.2 *Ascaris*. En-face view of lips and mouth.

The posterior end of the male bears ventrally, 50 pairs of *pre-anal papillae* in front of the cloacal aperture and five pairs of *post-anal papillae* behind it. The first two pairs of post-anal papillae are double. These papillae of the male help in copulation.

Excretory pore. It is situated mid-ventrally, a little behind the mouth.

Genital pore. It is present only in female and is situated mid-ventrally at about 1/3 distance from the anterior end.

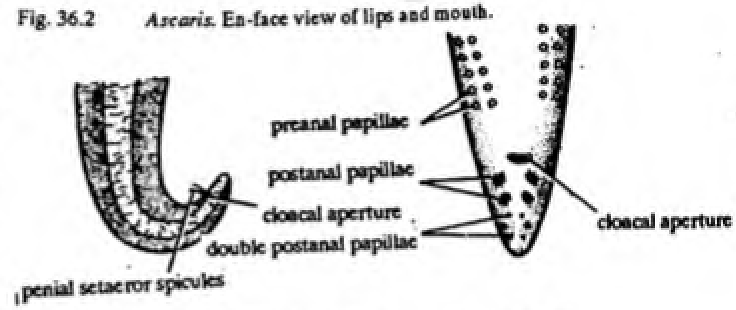


Fig. 36.3 *Ascaris*. Posterior end in lateral view and ventral view.

Anus. It is also present only in female. It is a transverse pore guarded by thick lips, lies mid-ventrally a little infront of posterior end.

Cloacal aperture. It is present only in male. It is situated mid-ventrally in front of the curved posterior end. Two chitinous *penial setae* or *penial spicules* are protruding through cloacal aperture.

BODY WALL

The body wall is made up of three layers.

(1) Cuticle

(2) Epidermis

(3) Muscle layer

1. **Cuticle.** The cuticle forms a thin transparent, elastic but resistant covering around the body. It protects the body against the action of digestive juices. It is secreted by underlying epidermis. Histologically, the cuticle is formed of several layers and can be distinguished into (i) Cortical layer, (ii) Matrix, (iii) Fibrous layer and (iv) Basement membrane.

   (i) *Cortical layer.* It is made up of dense keratin. It protects the animal from the digestive juices of host.

   (ii) *Matrix.* It is an elastic layer containing sulphur rich matricin.

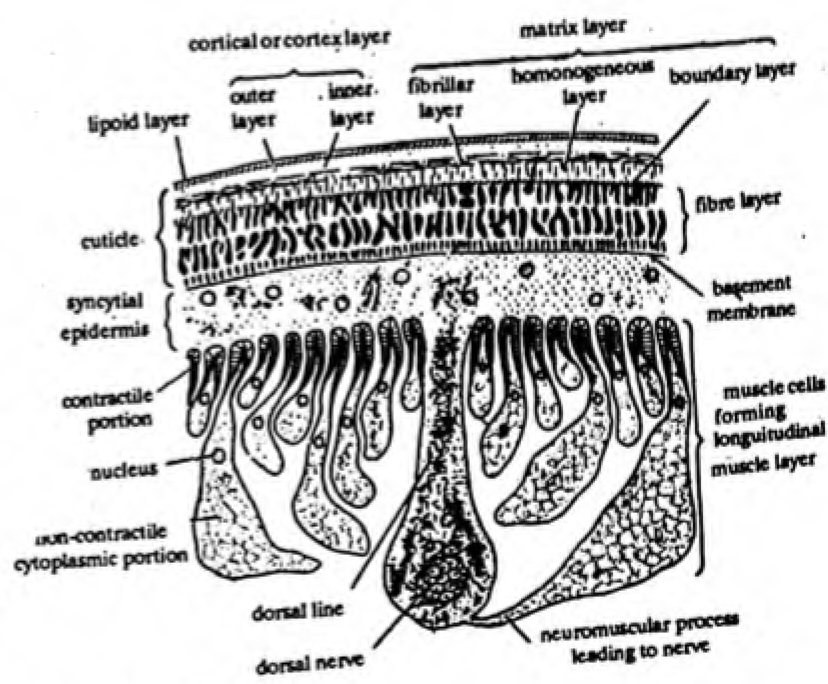


Fig. 36.4 *Body wall* in section.

(iii) ***Fibrous layer.*** It is made up of collagen fibres that cross each other obliquely.

(iv) ***Basement membrane.*** It forms the inner limit of cuticle.

Under electron-microscope the cuticle is made up of following layers:

(1) *Lipoid layer.* It is in the form of a thin osmophilic membrane, about 1000 A° thick.

(2) *Cortical or cortex layer.* It consists of (a) an *outer cortical layer* which lies as discontinous strips or rings around the body, and (b) an *inner cortical layer*.

(3) *Matrix layer.* It consists of (a) an outer *fibrillar layer* tranversed by branching canals, (b) a *homogeneous layer* with several radial striations, and (c) a *boundary layer* resembling the outer cortical layer.

(4) *Fibre layer.* It consists of collagen fibres arranged in three strata.

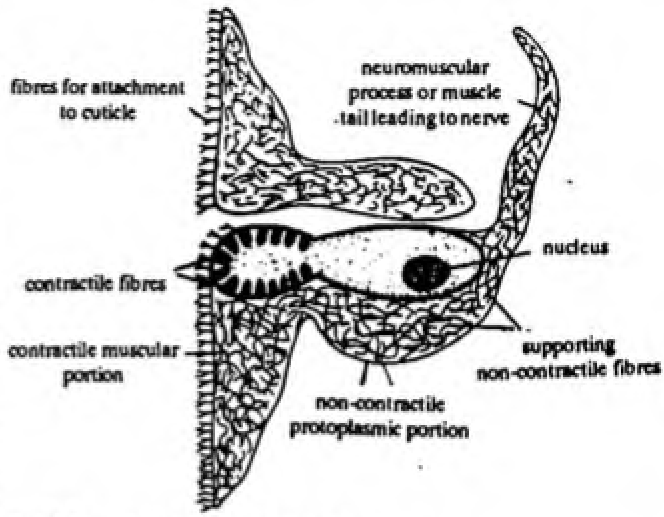


Fig. 36.5 *Ascaris.* A muscle cell in T.S.

(5) *Basement membrane.* It is a thin layer surrounding the epidermis.

2. **Epidermis.** It is *syncytical* in nature as it is having no cellular boundaries i.e. the nuclei are scattered in cytoplasm. It is thickened and projects into the pseudocoel as four longitudinal ridges called, *epidermal chords.* These are dorsal, ventral and lateral in position. The lateral chords are thicker than others, containing longitudinal excretory canals and lateral nerves in them. The dorsal and ventral are thin containing nerve cords and terminate towards the posterior end of the body.

3. **Muscle layer.** Beneath the ectoderm is a single layer of longitudinal muscles which is distinguished into four quadrants. Of them two are dorso-lateral and two ventro-lateral. Each containing about 150 muscle cells. The muscle cells are highly specialised spindle-shaped cells, distinguished into two parts lying below the ectoderm:

(a) *Fibrillar region.* Formed of contractile and non-contractile fibres arranged alternatively, it is found wrapped around the protoplasmic part.

(b) *Protoplasmic region.* It is the inner part of the muscle cell situated towards the pseudocoel. It is almost bladder-like in appearance and consists of a single nucleus.

There is a complete absence of circular muscles in nematodes.

PSEUDOCOEL

There is a large fluid-filled space between the body wall and the viscera. The fluid contains fibrous tissue in the form of fenestrated membranes and fixed cells. The epithelial lining of this cavity is absent hence cannot be a true coelom. The fenestrated membranes extend over the viscera and muscle layer from a single giant *pseudocoelocyte* placed on the dorsal side where pharynx connects with the intestine. Four more star shaped giant cells lie in relation to epidermal cords. Thus in all there are five pseudocoelocytes. The pseudocoelocytes and fenestrated membranes may be regarded as a kind of mesenchyme.

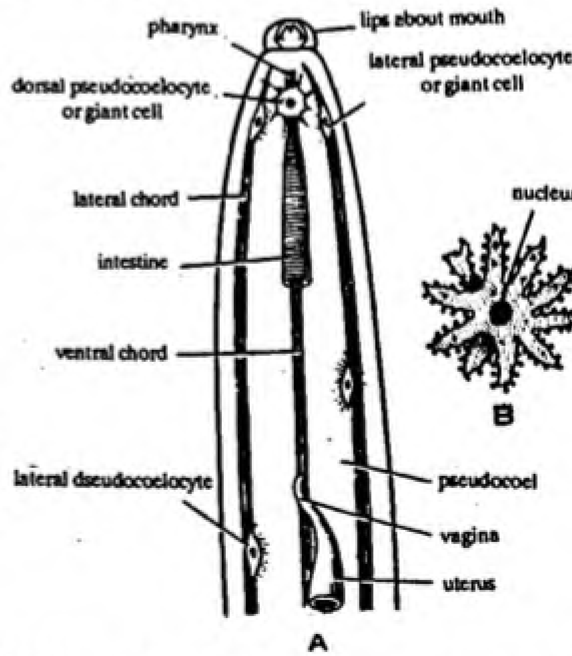


Fig. 36.6 *Ascaris.* A—Portion of giant cells in pseudocoel, B—Single giant cell.

In fact, the spaces are said to be large vacuoles in a few, enormous cells. A protein-rich fluid of characteristic, unpleasent

odour fills the cavity. This fluid may produce some of the toxic and inflammatory symptoms of ascarid infections.

LOCOMOTION

Locomotion is by means of longitudinal muscles which produce undulating movements of the body in the dorsoventral waves. The circular muscles are absent to counteract against longitudinal muscles, the hydrostatic pressure of body fluid against the cuticle serves the purpose.

DIGESTIVE SYSTEM

The alimentary canal of *Ascaris* is complete. It comprises mouth, pharynx, intestine, rectum and anus.

Mouth. It lies at the anterior end of the body. It is bounded by three lips-one mid dorsal and two latero-ventral in position. It leads into the pharynx.

Pharynx. The pharynx is muscular, about 10 mm. long. It is provided with a triradiate, cuticulate lumen, and has a wall composed of radially arranged, lumen-dilating muscles. A single, pinnately branched dorsal, and a pair of palmately branched subventral, uninucleate glands are embedded in the wall of the pharyns. These are unicellular structures discharging their contents into phanyngeal cavity. The wall is composed of syncytial epithelium. The pharynx is followed by the intestine. The pharynycal wall projects into the intestine as a phanyngeo-intenstinal valve.

Intestine. It is a long, thin, walled, dorsoventrally flattened tube which is devoid of muscles. The intestinal wall is formed of a single layer of elongated columnar cells lined externally by a *basement membrane* and a thin layer of *cuticle*. The free inner margins of columnar cells are produced into several finger-like projections called the *microvilli*. These form a *brush border* and increase the surface area for absorption.

Rectum. The intestine is followed by a short *rectum* which is also dorso-ventrally flattened. Wall of the rectum consists of tall columnar cells and is lined internally by cuticle and externally by muscle tissue. In male, the rectum opens into the *cloaca* which also receives the ejaculatory duct, while in female, it opens out through the anus.

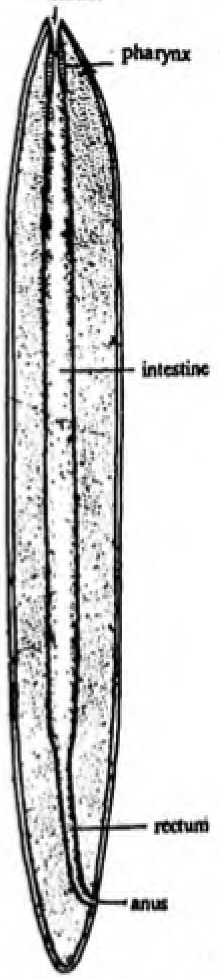


Fig. 36.7 *Ascaris.* Alimentary canal.

Anus. The anus is a transverse slit guarded by anterior and posterior lips and is provided with a special muscle, the *depressor ani*.

Digestion. *Ascaris* gets semi-digested or digested food from its host. So it does not require to digest food. However, it can digest semi-digest food by means of enzymes secreted by gland cells of pharynx and cells of anterior part of intestine. These enzymes can digest carbohydrates, proteins and fats.

Absorption. The cells of intestine generally absorb digested food. Excess fat and glycogen are stored in different tissue.

Egestion. By the contraction of dilator muscles attached to rectum undigested food is expelled out.

RESPIRATION

There being no special organs of respiration, but the parasite carry on anaerobic respiration by breaking

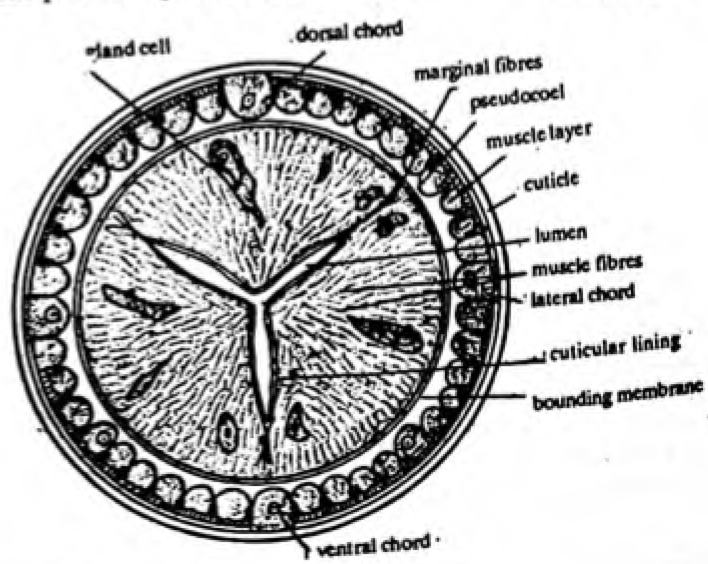


Fig. 36.8 *Ascaris.* T.S. body passing through phryax.

down glucose and forming carbon dioxide and fatty acid which are eliminated out through the cuticle. In the presence of oxygen, it respires aerobically. The small amount of haemoglobin in the body wall (muscles) and pseudocoel fluid takes up the oxygen even when it is present in low tension.

EXCRETORY SYSTEM

The excretory system of *Ascaris* is built entirely on a different plan. The flame cells or nephridia are absent. Renette cells of osmoregulatory function found in other nematodes are not found here.

In *Ascaris*, the excretory system is made up of a syncytium containing four or more nuclei. It consists of:

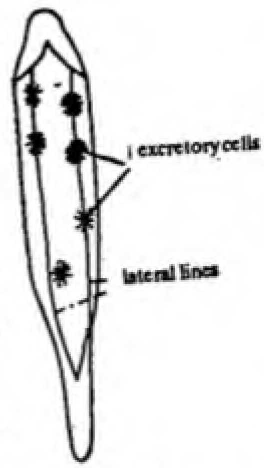


Fig. 36.9 *Ascaris*. Excretory system.

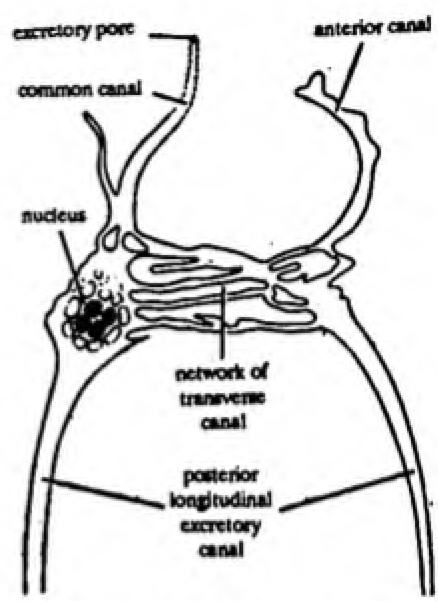


Fig. 36.10 *Ascaris*. H-shaped excretory system in anterior region of body.

1. **Excretory duct.** There is no excretory duct having two or more nuclei embedded into its walls. The excretory duct opens out through excretory pore.
2. **Excretory cell.** There is an excretory cell comprising two lateral excretory filaments running along each side of the body adjacent to the lateral chord.
3. **Commissure.** An excretory bridge is formed where two lateral filaments join. Each excretory filament contains an intracellular excretory canal. The intracellular excretory canals divide up into a network of canaliculi in the commissural region. Excretory products are believed to diffuse into the canals which secrete urea, which is eliminated out through the excretory pore.

NERVOUS SYSTEM

The nervous system consists of ganglia and nerves, all in close association with the ectoderm. The nervous system of *Ascaris* has been thoroughly studied by *Goldschmidt*. The number of cells taking part in the formation of entire system is apparently fixed and it is 162. There is a distinct *circumpharyngeal nerve ring* around the pharynx which connects a pair of *lateral ganglia*, a *dorsal ganglion*, a pair of *subdorsal ganglia* (each sub-divided into six smaller ganglia) and a pair of large *ventral ganglia* from these ganglia of the nerve-ring there proceed backwards eight nerves: a *mid-dorsal nerve* that passes through the dorsal epidermal chord; a *mid-ventral nerve* that passes through the ventral epidermal chord; a pair of *dorso-lateral nerves* that run just above the lateral chords; a pair of *lateral nerves* that extend through the lateral epidermis chords and a pair of *ventro-lateral nerves* that run just below the lateral epidermal chords. Of these, the ventral nerve is most prominant and is ganglionated through out its length, therefore, it is regarded as nerve cord. Posteriorly the nerve cord joins a *pre-anal ganglion.* The dorsal and ventral nerves are connected at intervals by asymmetrical *dorso-ventral connectives* throughout their length.

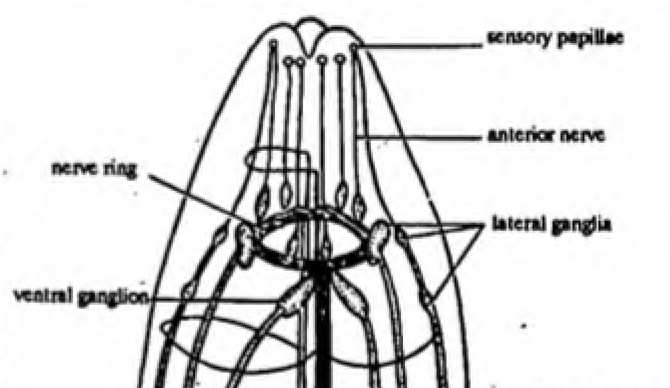


Fig. 36.11 *Ascaris*. Nervous system.

Similarly, the ventral and lateral nerves are also connected at interval by *ventro-lateral commissures.*

One of the six ganglia formed by sub-division of each lateral ganglion is known as *amphidial ganglion* which supply nerves to amphid of its side. The genital papillae of the male worm are innervated from special *bursal nerves.*

SENSE ORGANS

The sense organs include papillae amphids and phasmids.

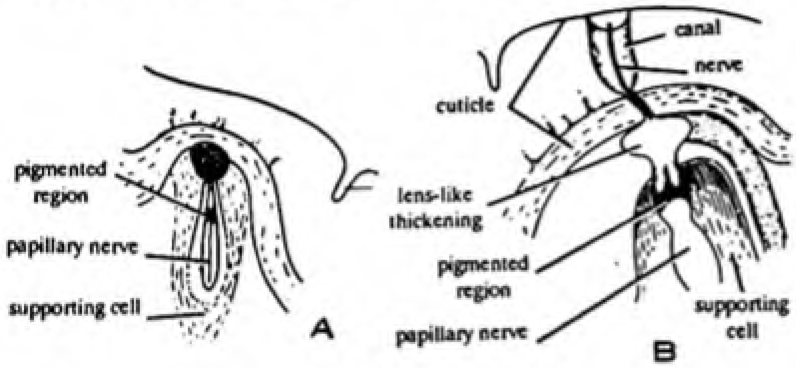


Fig. 36.12 *Ascaris.* Caplatic and labial papillae.

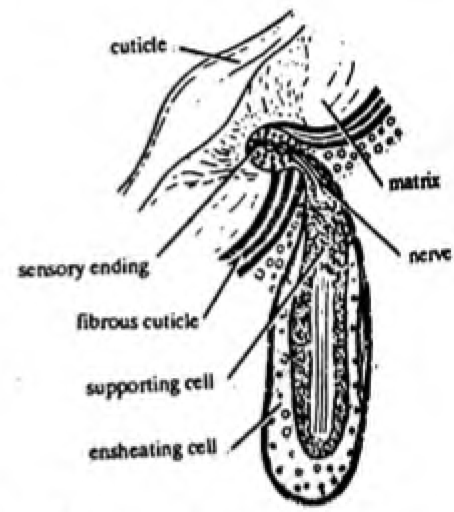


Fig. 36.13 *Ascaris.* Cervical papilla.

Papillae. Various types of papillae such as *labial, cervical* and *genital papillae* are present in *Ascaris.* A labial papila consists of a nerve axis placed inside a cuticular elevation surrounded by supporting cells. The dorsal lip has two double papillae, each consisting of a labial papilla on the medial side and a cephalic papilla on outerside. Each ventro-lateral lip has a labial papilla near its upper margin and a double papilla near its lower margin. The double papilla, a labial papilla towards the medial side and a cephalic papilla towards the outer side. Thus the lips bear six labial and four cephalic papillae in all. Genital and caudal papillae have a similar structure.

Amphids. These are two in number, one on each ventro-lateral lip a little above the labial papilla. An amphid consists of supporting cell opening out side by a pore and having a bundle of nerve-fibres that unite into one fibre. These are probably a chaemoreceptor.

A pair of *phasmids* occur on each side of the tail. Phasmids is the out let of a unicellular gland opening over a small papilla which is probably chaemoreceptor.

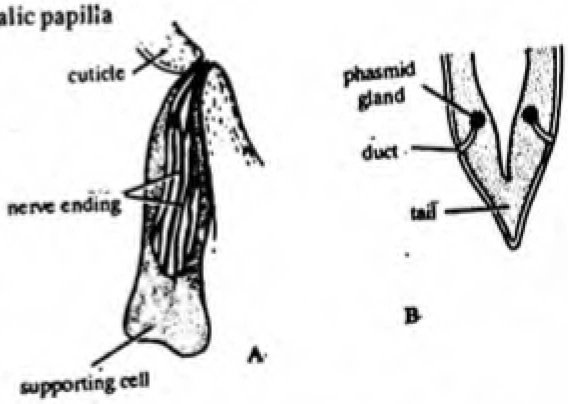


Fig. 36.14 *Ascaris.* A—Amphid, B—Phasmid.

REPRODUCTIVE SYSTEM

Sexes are separate and there is a well distinct sexual dimorphism.

1. Male Reproductive System

The male reproductive organs are:

1. Testis

2. Vas deferens

3. Seminal vesicle

4. Ejaculatory duct

5. Penial sac with penial setae.

1. *Testis.* The testis is a long thin, coiled and thread-like structure in the anterior part of pseudocoel. It represents *monorchic condition* (presence of single testis) and *telogonic* mode of origin of germ cells (*i.e.* germ cells developing only from the proximal part of gonad). The testis can be distinguished into three parts:-

(a) anterior solid part consisting of sex cells, (b) middle part and (c) Posterior part. The central axis of the tube is in the form of a solid *cytoplasmic rachis*, around which the clusters of amoeboid sperms in various stages of development.

It is continued posteriorly into the vas deferens.

2. *Vas deferens.* The vas deferens is a wide as the testis and the two cannot be marked externally. It is very short and leads into the seminal vesicle.

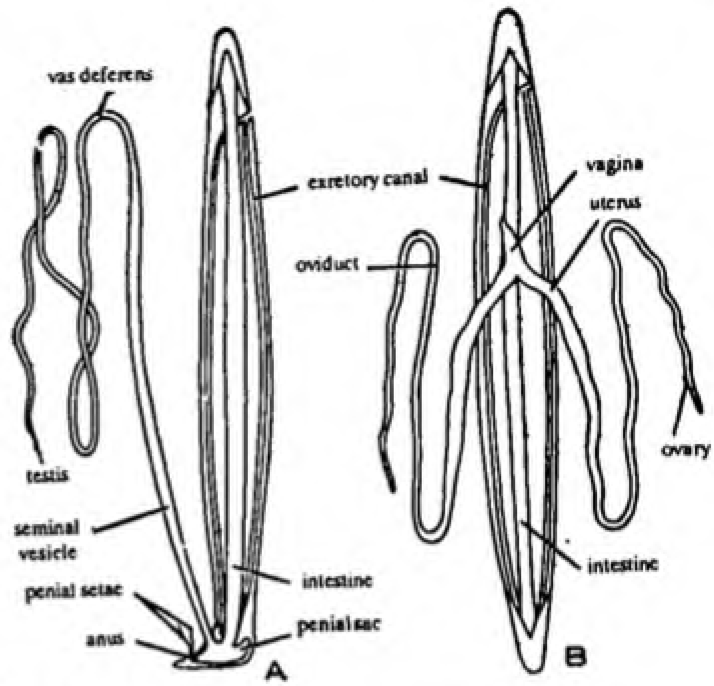


Fig 36.15 *Ascaris.* A—Male reproductive system, B—Female reproductive system.

3. *Vesicula seminalis.* The vesicula seminalis is a wide tube present in the posterior 1/3rd part of the body. It joins the ejaculatory duct.

4. *Ejaculatory duct.* It is a short, narrow but muscular tube opening into the cloaca, which leads outside by cloacal opening.

5. *Penial sac with penial setae.* On the dorsal side of the cloaca are a pair of sac-like structures called penial sac. These are formed by evaginations of the cloaca. Each pouch secretes and lodges a club-shaped *spicule* or *penial seta*. The spicula is enclosed in a sheath and consists of a cytoplasmic core surrounded by thick cuticle. Each spicule measures 2-3.5 mm. in length. The penial sac have special *protractor* and *retractor* muscles from their walls, the muscles push the spicule out and withdraw them back into the pocket.

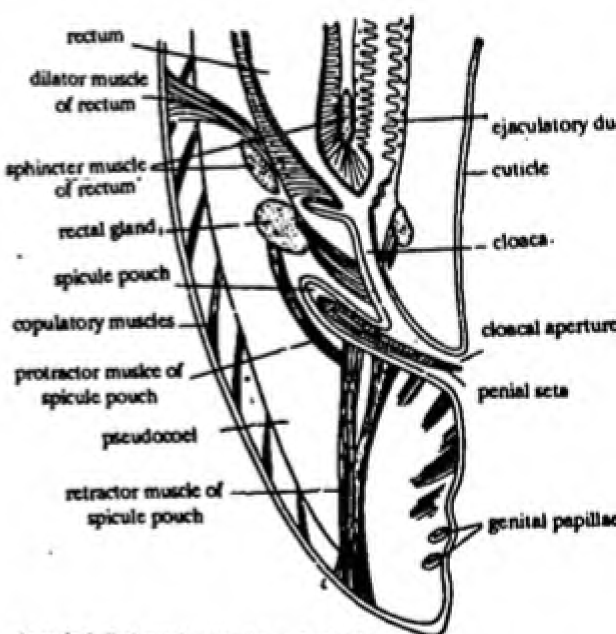


Fig. 36.16 *Ascaris.* L.S. through posterior end of male.

II. Female Reproductive Organs

The female reproductive organs include:

1. A pair of ovaries

2. Oviducts

3. Uteri

4. Vagina

1. *Ovaries.* The ovaries represent *didelphic* condition i.e. there are two ovaries. Each ovary is a long, thread-like, much twisted

and blind tubule occupying posterior 1/3rd of the body. Its walls consists of a single layer of cuboidal epithelial cells lined externally by basement membrane. There is no lumen, the central part is occupied by the cytoplasmic *rachis*, around which young eggs are clustered.

2. *Oviducts*. The oviducts are two thin ducts very similar to the ovaries. These open into the uteri.

3. *Uteri.* Each oviduct continues into a much wider, thicker and almost untwisted tube, the *uterus*. The wall of the uterus is composed of tufted cells, surrounded by a muscle layer with inner *circular* and outer *oblique* fibres.

4. *Vagina.* Two uteri join to form one vagina which opens to the outside by female genital pore or *vulva*, lying on mid-ventral side about 1/3 of the length of the body posterior to anterior end.

LIFE-CYCLE

Ascaris is *monogenetic* i.e., it requires only one host to complete its life-cycle.

1. **Copulation and Fertilization.** *Ascaris* copulate in the intestine of man. During the process sperms are ejected by male into vagina of the female. These move in the uterus where fertilization occurs. While moving further the eggs become covered by a chitinous cells and an outer irregular *albuminous coat.*

The eggs are round or oval (60 μ X 45 μ), light brown in colour and float in saturated solution of common salt. The unfertilized eggs laid by the mother may mix up with the fertilized eggs but the unfertilized eggs are larger (90 μ X 45 μ) and sink in saturated salt solution.

2. **Egg-laying.** The uteri of a single female may contain as many as 2,70,000,00 eggs (*Cram*, 1927), with an average daily production of about 2,00,000 eggs. The fertilized eggs are released in the intestine of host through the vulva. From the intestine of host they are eliminated along with faecal matters.

3. **Development.** The development takes

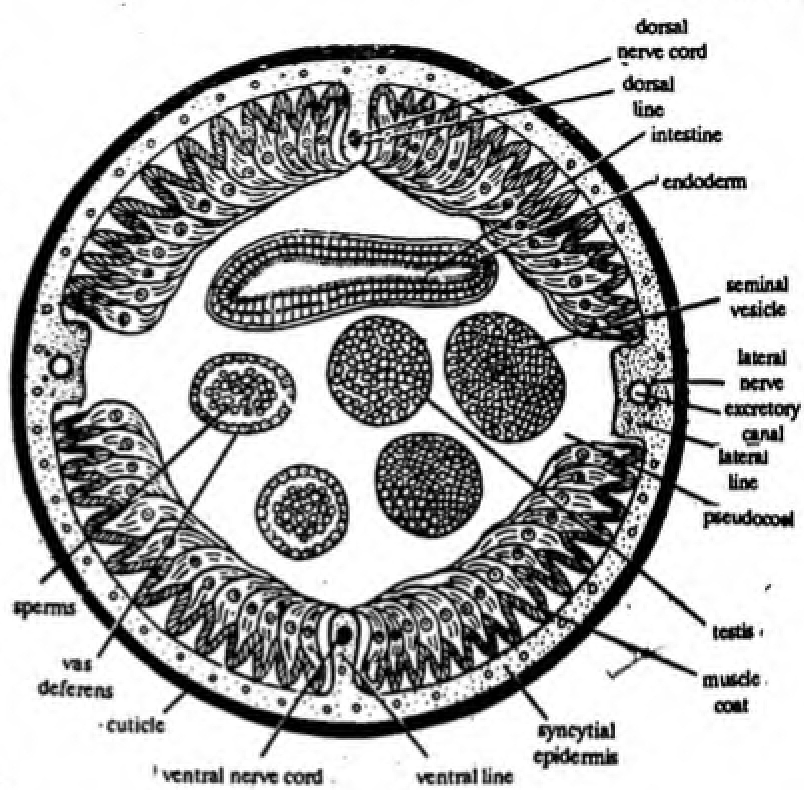


Fig. 36.17 *Ascaris.* Male T.S.

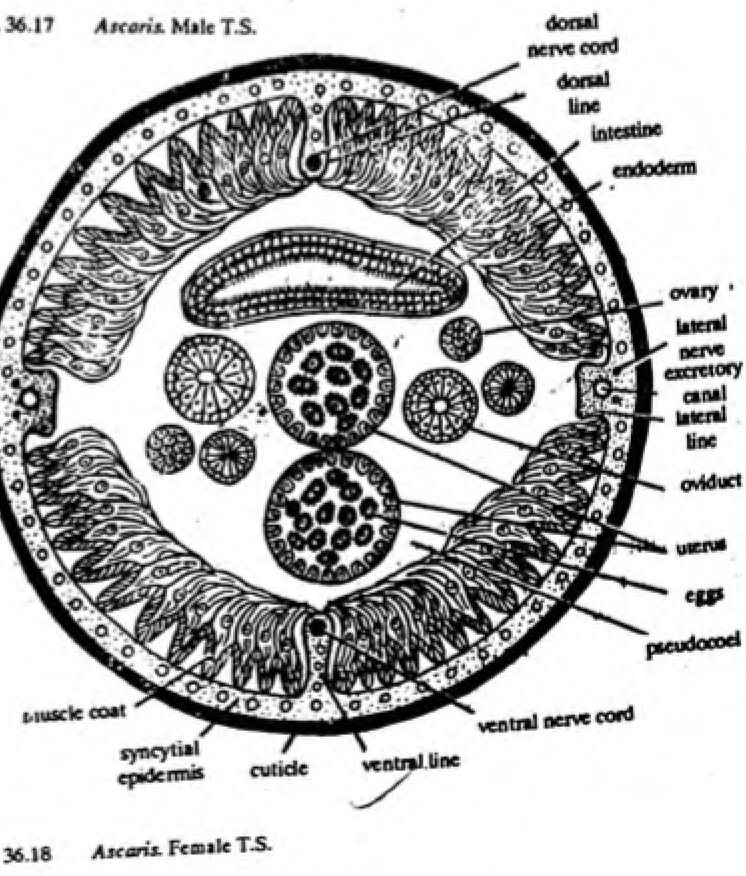


Fig. 36.18 *Ascaris.* Female T.S.

place at 85° F i.e. outside the body of man. It is stopped at 60° F and eggs gradually degenerated at 100° F. They can remain alive for years in moist soil.

Cleavage. The cleavage is spiral and determinate. The first division is transverse producing an upper *dorsal cell* (*AB*) and a lower *ventral cell* (*P*). The dorsal cell (*AB*) divides vertically into an *anterior cell* (*A*) and a *posterior cell* (*B*). Simultaneously, the ventral cell divides horizontally into *upper cell* (*EMST*) and *lower cell* (*P*). Thus the four-celled embryo has *T*-shaped appearance. The P_2 cell shifts towards right and comes to lie in front of the upper cell (*EMST*). The *A* and *B* cells divide together into right and left cells and by further divisions form the ectoderm of the embryo. The *EMST* and P_2 cells divide ii to *E*, *EMST*, P_3 and *C* cells. The offsprings of cell E form the endoderm, while the descendants of *EMST* constitute the mesoderm and a part of ectoderm. The cell P_3 divides into P_4 and *D*. The cells *C* and *D* divide and contribute to the ectoderm and mesoderm. The cell P_1 divides into G_1 and G_2 and forms the primordial germ cells. Thus blastula stage is attained. It undergoes gastrulation by invagination and finally develops into an active juvenile, representing the ***rhabditoid** stage*. Under favourable conditions of temperature, moisture and oxygen supply, it requires 10-14 days to reach the 1st stage larva. After a week or so it moults inside the egg shell and changes into the second stage larva. The hatching and further development of the larva is possible only if the egg enters the final host.

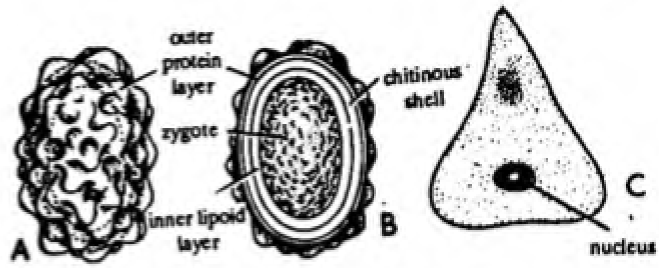


Fig. 36.19 *Ascaris*. A—Egg, B—Insection, C—A sperm.

Infection and Emergence of Larva. The eggs containing rhabditiform larva contaminate food and water. If someone takes this contaminated food or drink contaminated water the eggs reach the healthy man. This type of *transference* is called contaminative transference or infection. The shell of the egg is weakened in oesophagus and is dissolved in the intestine of the new host. The larva is about 200-300 μ in length and 14 μ in breath. It has fully formed alimentary canal, excretory and nervous system.

Primary Migration of Larva. The larva burrows the mucous membrane of the intestine of the host and through hepatic portal vein reaches the liver. From here through portal vein and post-caval reaches the right auricle of the heart. From here through pulomonary arteries reaches lungs. In lungs it moults twice. The first moulting takes place after 5-6 days (third stage larva) and second moulting after 10 days forming fourth stage larva. This larva now increases in size and is about 2 mm. in length.

Secondary Migration. From lung the larva reaches bronchii, trachea, larynx and finally to pharynx where it irritates causing coughing by which it re-enters the alimentary canal when the cough is swallowed. After reaching the intestine through stomach it moults fourth or last time. The young *Ascaris* becomes adult sexually mature within 6-10 weeks and begins its life-cycle again. the whole migration is completed within 10 days.

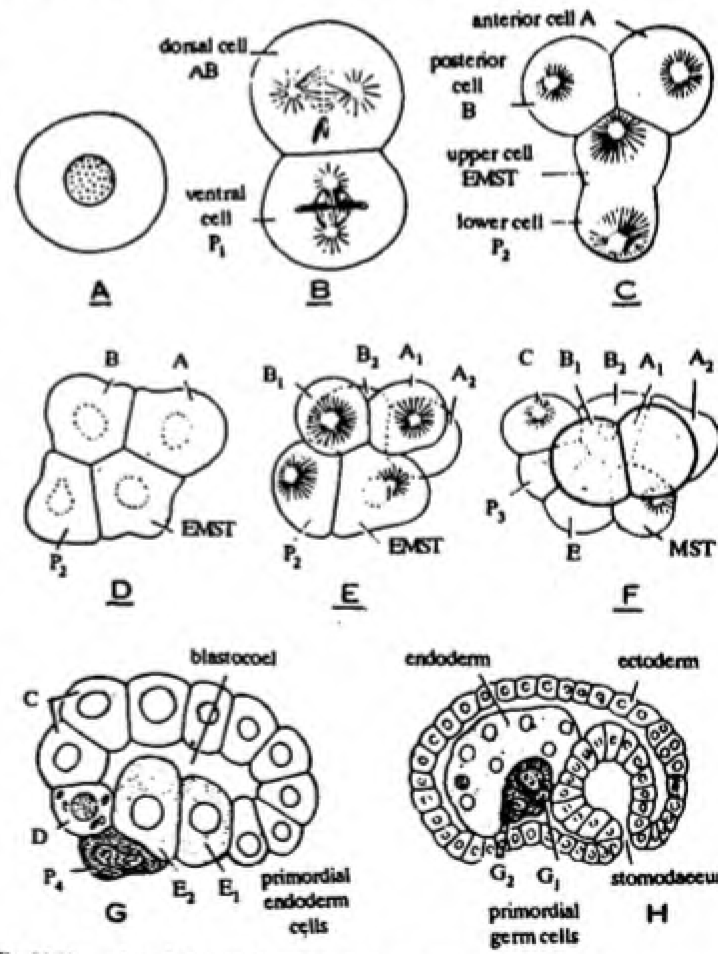


Fig. 36.20 *Ascaris*. Stages showing early development. A—Zygote, B—2 cell stage, C—4 cell stage (T-shaped), D—4 cell stage (rhomboidal), E—6 cell stage, F—8 cell stage, G—Medial sagital section through blastula, H—Median sagittal section through the embyro after invagination of stomodaeum and the primordial germ cells.

PATHOGENESIS

Ascaris is pathogenetic to man. when larvae migrate through the lungs, they cause lung-inflammation and fatal pneumonia. Sometimes, *fever, anaemia, leucocytosis* (presence of excess of white corpuscles in the blood) and *eosinophilia* result. In mature form, *Ascaris* may or may not disturb life-activities. Some abdominal discomfort and acute colic pains with *vomiting, diarrhoea* and *slight temperature* occur. Often masses of *Ascaris* block the intestine, in which condition they can only be removed by surgical operations. Several hundred thousands of worms are responsible for blockage and they are fatal. Appendicitis is also caused by the blocking of appendix by *Ascaris*. Toxic substances produced by *Ascaris* cause *convulsions*, (an involuntary contraction of the involuntary muscles of the body), *delirium*, (insanity or disorder in mind), *coma* and *generel nervousness*. *Sang* (1922) found that toxins produced by *Ascaris* cause interference with the digestion of proteins.

THERAPY

Several drugs like *Santonin, Antepar, Chenopodium* and *Hexylresorcinol* are used effectively under physician's directions. A mixture of *oil of chenopdium tetrachlorothylene* is usually successfully used. *Lamson* discovered that *hyxylresorcinol* is also very effective particularly when given as *crystoids* (in *gelatin* capsules) with fasting for 12 hours before treatment and 4 hours afterwards followed by sodium sulphate for removal of deal worms.

Hetrazan syrup is also very effective and nontoxic especially for children. *Piperazine hydrate, Alcopar* and Banocida are also recommended by several workersas antihelminthes.

PREVENTION

Adequate sanitation plus education should prevent ascariasis. Lack of adequate fertilizer in many parts of the undeveloped world means that night soil must be used to fertilize crops. Due to the resistance of *Ascaris* eggs to standard disinfectants, the situation would appear to be hopeless. There is a realistic solution. *Thitasut* (1961) reported that aqueous solution containing 120 ppm free iodine killed *Ascaris lumbricoides* eggs within 5 min or less and did not effect the flavour of leafy vegetables.

One of the problems in control is preventing children from ingesting eggs with contaminated soil. Given the habits of children throughout the world, including dirt eating, playing in contaminated soil and then placing their fingers in their mouths, ascariasis will unfortunately be with us until adequate sanitation is accomplished.

37

ANCYLOSTOMA

No group of the nematodes causes more injury to man or greater economic loss through attacks on his domestic animals then the members of the order Strongyloidea, the great majority of which are parasites of mammals. Many are blood suckers and cause severe injury to their hosts by loss of blood sucked by them or wasted from hemorrhages, the result is anemia.

SYSTEMATIC POSITION

Phylum	-	Aschelminthes
Class	-	Nematoda
Order	-	Strongyloidea
Genus	-	*Ancylostoma*

DISTRIBUTION

Human hookworm is endemic in warm, wet climates, but each species has some limitation on its distribution.

Ancylostoma duodenale is the common hookwork of man in tropical, subtropical and temperate regions of Asia, Africa, Pacific islands and South America. The other important human hookwork is *Necator americanus*, more common in the United States. Some other species of *Ancylostoma*, namely, *A. caninum* and *A. braziliense*, both in dogs and cats, and *A. malayanum* in bear, are also common.

HABITS

A. duodenale is the principle hookworm that infect humans. Following early morning, they are found in the small intestine lumen. Hookworms sometimes mature in abnormal hosts, and hosts other than man can be infected with human hookworms.

MORPHOLOGY

The name 'hookworm', is rather misleading because there is absence of hooks. The anterior hook-like bend probably is responsible for the common name, hookworm.

Shape and Size. The sexes separate. It is a cylindrical worm and whitish or grey in colour. The females are longer than males measuring 10-13 mm. in length and 0.6 mm. in width. The males measures 8-11 mm. in length and 0.45 mm. in width.

Buccal capsule. The anterior end of male and female is similar, somewhat narrower and curved dorsally. It bears a large cup-shaped buccal capsule for attachment to the intestinal wall. The buccal capsule has two *chitinous plates*, bearing teeth. The *teeth* make a tiny cut in the intestinal wall of the host and hook-worm sucks blood by the sucking action of pharynx.

Copulatory bursa. The posterior end of female is somewhat taper, bluntly rounded in the form of a cone and terminates into a minute spine.

The *posterior end* of male is broad and with an umbrella-like structure called *bursa*. The bursa is supported by fleshy bursal rays of definite arrangement.

DIGESTIVE SYSTEM

The digestive system is a straight tube comprising mouth, buccal capsule, pharynx, intestine, rectum and anus.

The pharynx has triradiate lumen lined with in turned cuticle and a wall composed of strong radiating muscle fibres extends posteriorly from the buccal capsule about 1/6 the body-length. The posterior region of pharynx is slightly dilated and embedded in its wall are three pharyngeal glands. One is median dorsal in position and a pair located subventrally. These glands open into the pharynx near the nerve ring. An intestine begins immediately behind the triradiate pharyngeal valve and proceeds as a straight tube to a short rectum. It is composed of a single layer of columnar cells. In the intestive the blood of host and other tissues are digested.

Musculature. The somatic muscles consists of a single layer of cells underlying a hypodermis and arranged into four longitudinal groups. These four groups are interrupted by four longitudinal quadratal chords located on the dorsoventral and lateral axes. Because muscle cells are limited to two in each sectioned quadrant, the worms are called *meromyarial.* The almost complete lack of transverse muscle cells.

EXCRETORY SYSTEM

The excretory system is rather complicated. Flame cells are absent in nematodes. The excretory system, consists of two canals embedded in the lateral chords and an isthums in the pharyngeal region. Surrounding or adjacent to the insthums, are other excretory structures including an excretory sinus into which tributaries from the lateral canals open and from which ventrally is given off a short, cuticulate, terminal duct. The duct opens at a ventral excretory pore. From the excretory sinus two large, subventral glands of uncertain function arise posteriorly. The tributory canals emerge from subventral glands and penetrate the lateral chords where they join the lateral canals. These lateral canals extend from the region of buccal capsule to the posterior end of the body where they end blindly.

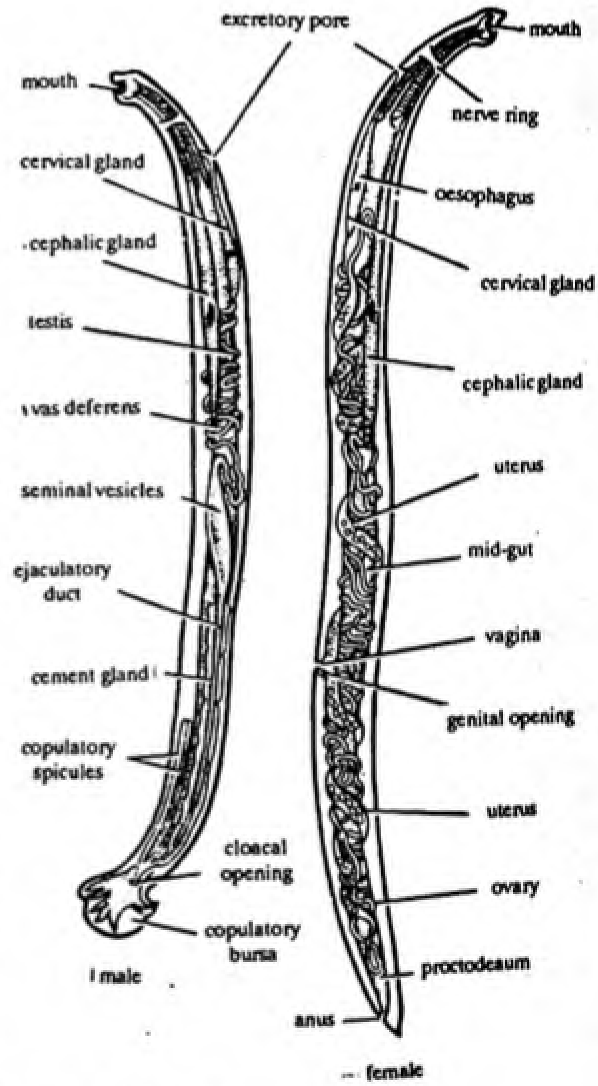


Fig. 37.1 *Ancylostoma duodenale.*

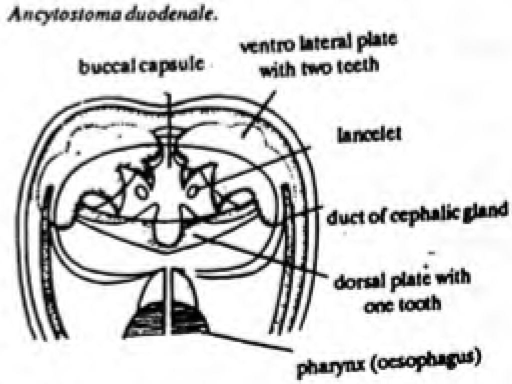


Fig. 37.2 *Ancylostoma.* **Buccal capsule.**

NERVOUS SYSTEM

Encircling the pharynx, in front of the excretory pore, is a nerve ring. From a large ganglion located on the ventral portion of the nerve ring, a larvae nerve runs in the ventral chord to the posterior end, and smaller nerves run in the lateral chords anteriorly and posteriorly. Four small nerves run forward from the ring to supply anterior end. These main nerve trunks are connected in a complicated fashion by nerve commissures.

REPRODUCTIVE SYSTEM

The male and female reproductive system are as follows:

Male Reproductive System. The tubular testis occupies the middle third of the body. It begins at the junction of the middle and posterior body thirds and runs in a random fashion to the middle of the body, from which point forward it coils loosely about the intestine. It leads posteriorly into vas deferens followed by seminal vesicle. Seminal vesicle which connects posteriorly to an ejaculatory duct leading directly to the cloaca. The ejaculatory duct, through most of its course, lies between two large, multicellular cement glands whose secretion apparently serves as an adhesive material holding the pair of worms together at copulation.

The posterior end of male bears a wide bursa, two copulatory spicules and a gobernaculum. The bursa is a long, wide, bilaterally symmetrical structure, with supporting, paired, fleshy rays having a specific distribution. The two spicules are long and slender. Each measures 2000 μm. They are protruded and retracted by special muscles and help in the transport of sperms to the valva of female. The gubernaculum is a hard piece present on the dorsal wall of cloaca. It is said to be used to guide the spicules.

Female Reproductive System. Two much convoluted orarian tubules, one anterior and other posterior to the level of gonopore are present. From the ends of the ovaries, nearest the vulva, short, narrow oviducts carry the ova into wider seminal receptacles where fertilization occur. From each seminal receptacle arises a muscular uterus that terminate into vagina. Two vaginae join and then open to the surface at the vulva.

LIFE-CYCLE

Copulation and fertilization. Fertilization is internal and during copulation the bursa of male is applied on the vulva of female. The female *Ancylostoma* lays about 20,000 eggs per day. The egg is about 60 x 30 μ. These are passed along the host faeces at four-celled stage and do not develop further until exposed to air. Under favourable conditions the embryo hatches out of the egg in less 24 hours in the faeces contained in the mud.

Larval development. Under favourable conditions of moisture, oxygen supply and temperature (68-85°F) the embryo develops and hatched as larva.

The hatched larva is the first larval stage or the fist *'rhabditiform larva'*. It has mouth, pharynx and a simple intestine. It feeds on bacteria and organic debris in the faeces and grows rapidly. At the end of 2nd day it undergoes first moult and changes into second stage larva (or the *strongyliform larva*). At about 5th day it undergoes second moult to become *filariform-juvenile*. This is the infective non-feeding stage. The skin of the second stage larva is retained as a protective sheat. The larvae live in the upper half inch of soil.

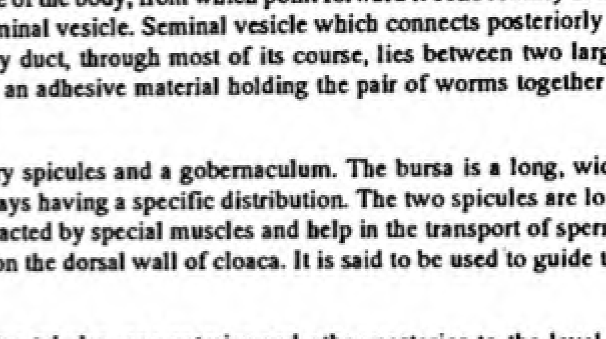


Fig. 37.3 *Ancylostoma*. Copulatory bursa.

Infection. The third stage or the filariform juvenile represents the infective stage. It may remain alive in the moist soil for nearly four months without feeding. When a man walks bare-footed on the infested soil, the larva penetrates the skin. Infection can also occur by ingestion of infective juvenile in food or drink.

Larval Migration. Within 24 hours of infection, the larvae reach the blood-vessels. From here they are carried first to the right ventricle of the heart and then to the lungs. From lungs the larvae assend the trachea and to the pharynx. In pharynx they are swallowed through oesphegus and finally reach to the small intestine. In the ileum they become attached to the mucous lining and feed on blood of the host. In 5-6 weeks, they moult twice to become adult and begin to reproduce. The normal life-span of hookworm is 5-7 years.

Pathogenecity. Hookworm is the most pathogenic parasite of man.

1. *In skin.* The penetrating larva causes 'ground itching' or 'water sore' characterised by itching the inflammation of skin.
2. *In lungs.* The migratory larvae when in large number cause haemorrhage and bronchial pneumonitis.
3. *In intestine.* Adults in the intestine produce stomach pain, abdominal discomfort, nausea, food fermentation, diarrhoea. But

the principal effects are due to anaemia, resulting from constant sucking of blood. It leads to palpitation of heart, eosinophilia and sucking of blood and even collapse. Hookworm infection in children causes retarded mental and physical growth and sometimes to dizziness, insomnia, optical illusions, general nervousness and fidgety movements.

TREATMENT

A number of highly effective antihelmintics are available for use in humans, including piperazine, bengimidazoles, thymol, carbon tetrachloride and Hexlyresorcinal.

EPIDEMIOLOGY AND CONTROL

Transmission of hookworms in the human population is dependent on a combination of following biological and climatic factors and human culture.

1. Egg production of female worms.
2. Longevity of adult worms.
3. Development and survival of the free-living states as related to weather and climate.
4. Immunity of the definitive hosts.
5. Nutritional level of human population.
6. Technological and economic level of the area.

A total campaign against hookworm disease involves:

1. Mass chaemotheraphy.
2. Samitary disposal of human waste.
3. Wearing shoes.
4. Administration of ions salts.
5. Ensuring adequate dietary protein.

38

WUCHERERIA (= FILARIA) BANCROFTI

The parasite gained importance after Manson's findings in 1878 that a mosquito acts as the transmitted agent for this parasite. *Manson* (1887) studied the life-cycle of the parasite and suggested reasons for the marked diurnal periodicity exhibited by filaria in the peripheral human circulation. *Vogel* (1928) and *Fain* (1951) gave accounts of the adult structure. The importance of this parasite to mankind is underlined by the fact four international meets were held in late 1960's to discuss the epidemiology, pathology and control of this worm.

SYSTEMATIC POSITION

Phylum	-	Aschelminthes
Class	-	Nematoda
Sub-class	-	Phasmidea
Order	-	Filaroidea
Genus	-	*Filaria*
Species	-	*bancrofti*

DISTRIBUTION

Filaria, the most important human filarial parasite, is widely distributed in a tropical and subtropical circumglobular belt. But the parasite is not evenly distributed or uniformly prevalent throughout any country. It occurs almost entirely in coastal areas and islands where there is a fairly long hot season with high humidity. In Africa found on the Mediterranean and east and west coastal areas but not in the interior of Central Africa. In Asia it is prevalent on the coasts of Arabia, India, Malaya, Formosa, and north to China and the southern part of Korea and Japan. It is prevalent in practically all the East Indian and South Pacific Island.

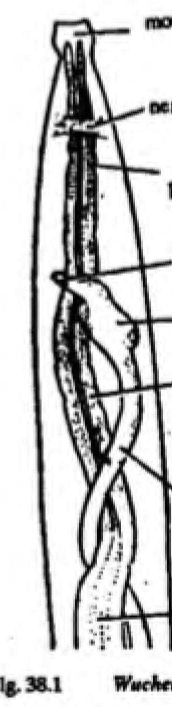


Fig. 38.1 *Wuchereria bancrofti.* Anterior part.

HABITS

It is a *digentic parasite* i.e. its life-cycle is completed in two hosts. The *definitive host* in man where it lives in the lymphatic system. The *intermediate host* is mosquito (*Culex*, *Aedes* and *Anophiles*).

MORPHOLOGY

The adult worms are found in the lymphatic vessels and lymph nodes of man only.

Adult worms are hair like, transparent nematodes often creamy white in colour. They are filiform and both ends are tapering. The posterior end terminates in a slightly rounded swelling. The male is about 40 mm, in length while thickness is about 0.1 mm. The posterior end of the male is curved ventrally and has two spicules of unequal length. Female measures 65-100 mm, in length and its thickness is about 0.2 to 0.3 mm. The tail end of the female is narrow unbent and abruptly pointed. Although females, liberate active embryos yet they are really *ovo-viviparous* i.e., lay eggs with well developed embryos. Males and females usually remain coiled and can only be separated with great difficulty. Females are more in

number than males. The life span of the adult worm is about 4-5 years.

LIFE-CYCLE

Copulation takes place when individuals of both the sexes are present in the same lymph node. Female, releases numerous (about 1,000) first stage larvae or jureinule called *microfilariae.* These larvae are surrounded by delicate membranes or sheaths and measure 225-300 mμ long and 10 mμ in diameter. When living they are colourless and transparent and may or may not be surrounded by sheaths. In order to identify them they are usually stained. The body will then be found to contain a column of nuclei, broken in definite places. The peripheral ones are a nerve ring anteriorly, an excretory pore or 'V' spot, an excretory call somewhat further back, a few genital cells posteriorly and an and pore. The tail is devoid of nuclei.

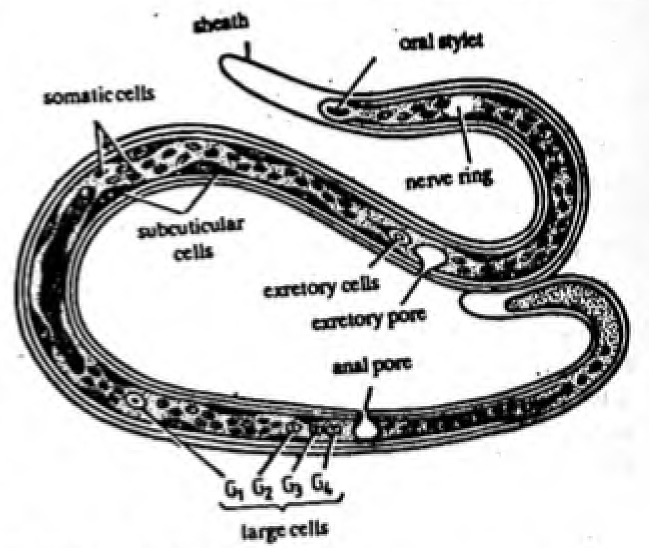


Fig. 38.2 *Wuchereria.* Microfilaria.

The microfilairae appear in the peripheral circulation chiefly between 10 P.M. and 4 A.M. There has been much speculation and experiment to determine the reason for this periodicity. According to one view, the larvae are concentrated in internal organs such as lungs (*Smyth*, 1976) during day time, but they circulate in the blood at night for the transmission to the mosquitoes. Another view holds that embryos are born at a certain time each day and are then destroyed in the host within ext 24 hours. According to *Manson-Bahr* and *Muggleton*, the nocturnal periodicity of microfilariae in peripheral blood of man is an adaptation to maintain a tryst with the night biting species of mosquito.

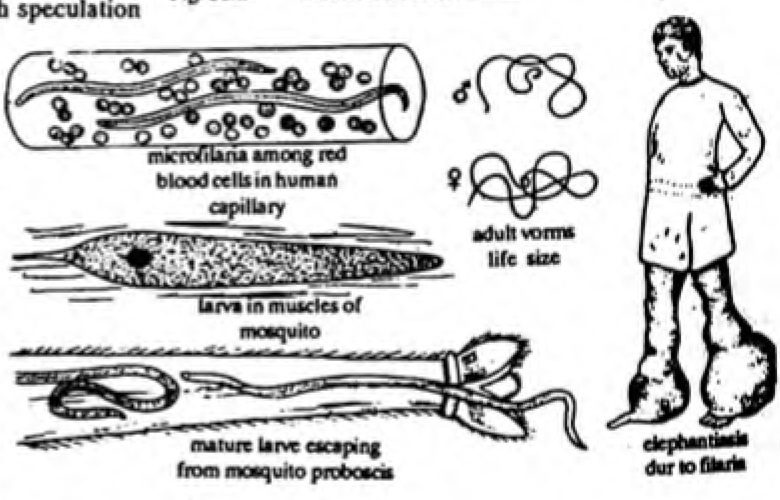


Fig. 38.3 *Wuchereria.* Stages in the life-cycle.

The further development of the microfilariae depend on their being sucked with blood by certain species of mosquitoes. In order to infect mosquitoes there must be about 15 or more microfilariae per drop of blood, a high concentration of 100 or more per drop of blood is fatal to mosquitoes.

Shortly after being digested by a mosquito the microfilariae penetrate through the stomach wall and migrate to the breast muscles. Here the embryos lie length wise between the muscle fibres. The size of body is reduced to half its original size length, but grows several times as thick. It now changes into a sausage-shaped creature.

The sausage shaped larva measures 1.5-2.0 mm. in length and 20-30 mμ in diameter. As these changes take place the larva moults twice and become infective. The formation of the infective stage takes about 10-14 days and occurs best at 28°C and a relative humidity 90%. Digestive system, body cavity and genital organs also become well developed. This is called third stage larva. This infective stage reaches into the head of mosquito and finally into the proboscis on about 14th day. There are several larvae, coiled up in mosquito ready for infection in man. The complete development of microfilaria in the mosquito is from 10-20 days.

Infection and adult stage in man. When the infected mosquito bites a man, the third stage larvae are deposited, usually in pairs, on skin near the site of puncture. Later on the larvae enter through the puncture or penetrate through the skin. From here they reach the lymphatic vessels and settle down at same spot, i.e. inguinal, scrotal or abdominal lymphatics. The larva grows

into adult. After a period of 5-18 months, larvae become sexually mature and start new generation of microfilariae.

PATHOGENIC EFFECT

The pathogenic effect of *Filaria* produced by the adult *Filaria* either living or dead. When microfilariae are circulating in the blood, no pathogenic effects are produced. The adult worm causes an inflamatory reaction of the lymphatic system or *lymphangitis.* The metabolities of the growing larvae cause allergic manifestations such as urticaria, figutive swellings i.e., raised, painful, tender red areas of the skin at extremities and *lymphoedema.*

The cause of lymphangitis are mechanical irrigation, liberation of metabolites, absorption of toxic products, and bacterial infection. Later when lymphetics passage are severely blocked by the adult and microfilariae *elephentiasis* results.

TREATMENT

Drugs for *filaricidal* reactions can be grouped into 3 main groups:

(1) on adult worms-Mel w, an arsenical preparation.

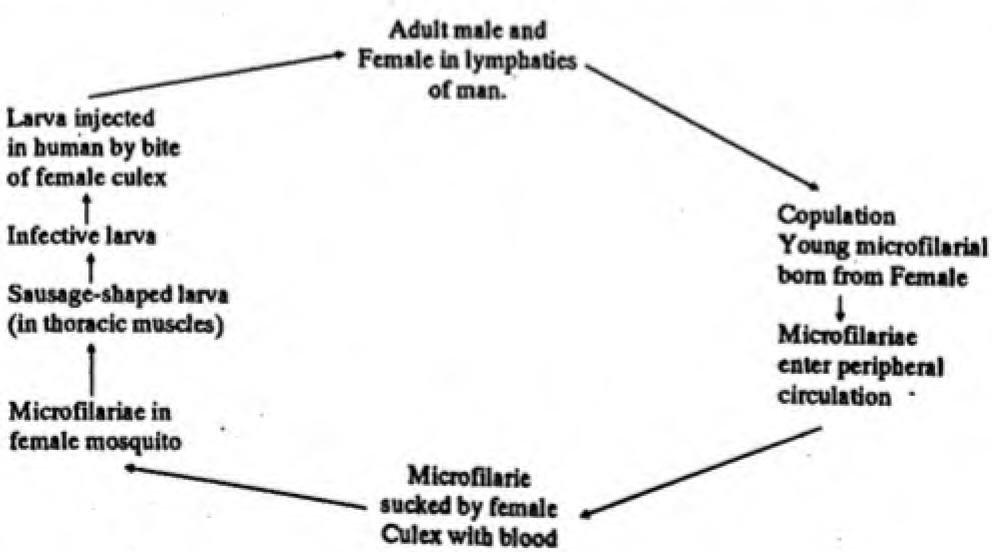
(2) on microfilariae-Diethycarbamazine (Hetrazan).

(3) on infective larvae and immature adult worm-para-melaminyl-phenylstibonate (MSb).

PROPHYLAXIS

It includes:

1. Killing the adult intermediate host i.e. mosquitoes.
2. Use of selected insecticides to kill the adult and larval stages of mosquito.
3. Use of wire netting at door and windows of human dwellings to prevent the entry of mosquitoes.
4. Administration of diethylcarbamagine (DEC) mixed in common salt has shown encouraging results.



Life-cycle of *Filaria bancrofti.*

39

PARASITISM AND PARASITIC ADAPTATIONS

Parasitism is such an association between two animals of the same or different species in which one lives on or inside (parasite) the body of the other (host) receiving nourishment and shelter without any compensation for the host. Therefore, in this association the parasite is benefited and the host is harmed.

ORIGIN AND EVOLUTION OF PARASITISM

Parasitism is a secondary mode of life and has arisen from pre-living condition. Parasites living inside the bodies of their hosts (*endoparasites*) are the most successful ones. Between the endoparasitic life and free-living life, intermediate stages are not uncommon, proving that parasitism did not evolve all of a sudden but followed a series of steps in succession.

Living together or symbiosis started when smaller animals occasionally taking shelter temporarily on the body of some larger form. When this temporary shelter was repeatedly used, the association of two organisms become more intimate and the small organism got not only the shelter but also free transport and nourishment in the form of bits from the host, without interferring with the activities of the host or injuring it. Such a simple symbiosis is known as *commensalism* and the benefactor is called a *commensal.*

Still later, the commensal started living within the body of the host without doing any harm to the host. Thus a commensal may be firstly an *ectocommensal* and later an endocommensal. Symbiosis sometimes proves beneficial to the host. Thus both the organisms benefitting each other mutually the host becomes so dependent upon the commensal that it cannot get along without it. This kind of association is called *mutualism.*

Commensalism usually evolves not in the direction of mutualism but towards a deeper association, the *parasitism.* A commensal that at first takes shelter, then bits of food and finally starts to feed on body tissues of the host so that the latter has to suffer with some harm.

DIFFERENT TYPES OF PARASITISM

The parasitism can be classified into following categories:

1. *Accidental.* When a free living animal accidently reaches inside the body of the host then it leads a parasitic life for some time.
2. *Facultative.* When the animal can live both as parasitic or free-living, they are known as facultative parasites.
3. *Obligatory.* These animals can not lead a free life, therefore, they need a suitable host for them. The obligatory parasitism is of different types:
   (a) *Ectoparasitism.* The animal lives on the external surface of the body of the host.
   (b) *Endoparasitism.* The animal lives inside the body of the host in various organs and systems.

EFFECT OF PARASITISM UPON THE PARASITE

Changes from a free-living condition to a parasitic life involves changes in the body of the animal. Due to parasitic mode of life certain new structures are developed due to new environmental requirements similarly certain characters, which are of no

use for new environment, are lost. All such changes are included with effect on parasitism on the parasite. The helminths are modified morphologically as well as physiologically to live in their particular environment.

I. Morphological Adaptations.

II. Physiological Adaptations.

I. Morphological Adaptations

These are of two types (i) Structure which are partially or wholly lost. (ii) Structures which have developed a fresh.

Degenerations

1. *Organs of locomotion.* Locomotion is actually an effort for procuring food. But parasites habitually inhabits such places in the host's body, where sufficient food is available without effort. Thus, the organs of locomotion, such as the cilia of free-living turbellarians, are absent in the parasitic forms. It is interesting to note that the locomotory organs are duly present in free-living larvae of parasitic forms; the miracidium possesses cilia and the cercaria possesses a tail for locomotion.
2. *Organs of nutrition.* Food of the parasite comprises the readily available digested or semidigested food of the host. Therefore, there is a reduction in trophic organs. In trematodes, there is an incomplete gut and in most of them, suctorial pharynx is present. In cestodes, the mouth and alimentary canal are lacking because digested food is readily available in the gut of the host.
3. *Nervous System.* Living safely in a more or less stable environments, parasites do not need a complex nervous system.
4. *Sense Organs.* Progressive parasitism is accomplished by the loss of sense organs. The sense organs, necessary for quick and efficient response to the stimuli, are associated with the free active life. In the host the environment is more or less uniform and so the sense organs are not essential. Hence they are reduced. The endoparasites are generally provided with tangoreceptors.

Neoformations

1. *Protective covering.* There are no epidermal cells in the adult, instead of which the body is covered by a several-layered thick cuticle which protects the parasite from the juices of the host.

   The outer surface of the cuticle is formed of a fibrous protein called *keratin.* The cuticle may provide with scales.
2. *Organs of attachment.* For a firm grip on or in the host's body, some special organs of adhesion are necessary. The flatworms, for this purpose, are variously armed with suckers, hooks and spines. The suckers themselves may be with or without hooks and spines.
3. *Organs for penetration.* The parasites must penetrate the host's body for entering it. So the parasites develop certain structures for penetration. Miracidium larva has a conical process at the anterior end called *apical papilla.* There are a pair of penetration glands inside the body near the anterior end.
4. *Suctorical pharynx.* All the endoparasites except cestodes have a suctorial pharynx by means of which liquid food is sucked into the intestine. Intestine is always branched.
5. *Reproductive system.* It is highly developed and the production of eggs is prolific. The parasitic flatworms are hermaphrodite. In cestodes the reproductive organs are much more elaborate and are repeated in each proglottid. Each mature proglottid possesses one set (*Taenia sollium*) or two sets (*Diphylidium*) of male and female reproductive organs. In each gravid proglottid all other organs of the system degenerate to make room for the uterus which is greatly enlarged and branched to accomodate a large number of eggs.

II. Physiological adaptations.

1. *Protective mechanism.* In the alimentary canal of the host the parasite protects itself from the action of digestive juice of the host.

   The tapeworms accomplish this (a) by stimulating the walls of the gut to secrete mucus, which then forms a protective

clothing around the parasite, (b) by secreting antienzymes to neutralize the digestive enzymes of the host, and (c) by probably continually renewing their protective body covering *i.e.*, tegument. Lime cells in the body wall of tapeworms nutralize the acids produced by the host. Blood parasites are known to withstand the effect of antibodies and phagocytes of blood by some mechanism.

2. *Osmoregulation.* The osmotic pressure of body-cluid of endoparasites, especially in case of trematodes, is almost the same as that of the host so that there is no necessity of osmoregulation. But in the intestinal tapeworms, the osmotic pressure is slightly higher than that of surrounding medium. This permits absorption of nourishment through their general body surface from the surrounding medium.

3. *Anaerobiosis.* The pH tolerance of the parasite is high from 4-11. The intestinal parasites live in an environment completely devoid of oxygen. The respiration is of the anaerobic type consisting of extracting oxygen from the food stuffs. In the absence of oxygen energy is obtained by the fermentation of glycogen in which glucose in broken into lactic acid.

4. *Periodic appearance.* There are some parasite which appears at definite period. The larvae of *Wuchereria bancrofti* circulate into the peripheral blood circulation in the night between 10 P.M. to 4 A.M. for further development they require *Culex* mosquitoes. The *Culex* bites a man at night *i.e.* nocturnal in habit. Their migration is correlated with the nocturnal habit of *Culex*.

5. *Neoteny.* It is a special phenomenon in which the larvae are capable of reproduction and they produce young ones. *Ligula* (Cestoda) exhibit neoteny and this can be considered an adaptation for parasitic mode of life.

6. *High fertility.* Parasites develop enormous fertility, producing millions of fertile eggs. This is correlated with the passive Transference of the infective stages of the parasites from one host into another. While passing through the complex life-cycle, these potential offsprings face several hazards as a result of which a very small percentage of the total eggs produced reaches adulthood. For example in *Fasciola*, if the eggs fall in water, if the first larva (miracidium) finds a suitable snail within a limited period, if the cercaria encyst, on vegetation within the reach of final host and if the metacercaria happen to be ingested by the proper final host, only then the life-cycle is completed. Not only this, the larval stages themselves multiply say for example sporocyst produces a number of rediae. A single redia produces a number of cercaria larvae. Similarly a single hexacanth may multiply by generating buds which produce daughter and grand daughter scolices (hydratids of *Echinococcus*).

7. *Transferance of eggs or infective stages.* This is another major problem for which the parasites have to develop adaptations. Transference from one host to another is either:

(i) **Active transfer.** This is a less common method. The infective stages are actively transferred to final host. The larval stages of most parasites bore directly through the skin of their host such as the larvae of hookworms and schistosomes.

(ii) **Passive transfer.** This is the most common method and usually results from the careless habits of the host and is achieved in several ways such as contamination, contagion and inoculation. Oral infection occur when the host takes uncooked food or contaminated water. The intermediate host, such as mosquitoes, inoculate parasites when they suck the blood of hosts.

EFFECT OF PARASITISM ON THE HOST

Although a given host may be immune to a parasite by virtue of being constitutionally unstable as a habitat, it is important to recognize that the establishment of a parasite in a host also involve the capacity of the parasite to resist reactions of the host that might be deleterious. These host reactions would include inflammatory tissue responses and immune responses of a humoral character. Both types of host reaction occur in most parasitisms involving characters. The immune system in higher vertebrates is composed of several tissue components. These include fixed cells of spleen, liver, lymph nodes and thymus. There is also a system of mobile phagocytic cells, originating mainly in the body, such as undifferentiated mesenchyme cells. Some of these cells have the ability to elaborate antibodies, which may be released from cells into the body fluid. These globulins may combine with parasitic organisms or their products and produce an inhibitory effect. A peculiar organisms or their products and produce an inhibitory effect. A peculiar type of immunity develops in man due to the presence of tapeworms; after the first infection no further infection is possible as long as the primary infection lasts, this is termed *premunition*.

The possible role of interferons in the immunity of hosts to animals parasites should be also mentioned. These substances are produced in response to the presence of a foreign agent. Unlike antibodies, they seem to render host cells until as habitations

for intracellular parasites.

There are other types of host response that cannot be clearly recognized as immune in characters. For example, the changes in the fatty acids found in the alimentary canal of animals infected with the tapeworm, *Hymenolepis*, or the marked modification of the amino acid composition of bile in sheeps harboring *Fasciola hepatica* are obviously host responses to the presence of parasites concerned. It would be of great interest to determine whether such response are beneficial to the parasites, to the host or to neither.

CHARACTERS & CLASSIFICATION OF ANNELIDA

All the invertebrate animals, who possessed a soft-body, usually bearing a general resemblance to the common earthworm were included in the old phylum Vermes and were called worms. Thus the old phylum Vermes represented a heterogenous assemblage of no exact classificatory value. *Cuvier* was first who pointed out the fundamental differences between the lower unsegmented worms and the higher segmented worms in 1798. Now-a-days lower unsegmental worms divided into three phyla - Platyhelminthes (includes flat worms), Nemathelminthes (round worms) and Trochelminthes (wheel worms). *Lamarck* gave the name Annelida (ring worms) to the higher segmented worms.

Term Annelida is derived from two words one is Latin (*annulus* = a ring) and a Greek (*eidos* = form).

Annelids are typical animals that burrow or crawl upon the bottom in the ocean or in fresh water. Some are free swimming, at least during the breeding season, and others are adapted to life in moist soil. Many marine species build permanent tube which they inhabit; in other species the tube is temporary, like a burrow, and may be abandoned for another. Some annelids are actively predaceous, seizing their prey in well developed jaws, others notably permanently tube dwelling polychaetes, feed upon microscopic particulate matter brought in by ciliated tentacles or entrapped in sheets of mucus.

Characters:

1. Annelids are bilaterally symmetrical with elongate vermiform body.
2. The body is metramerically segmented and ringed appearance with the serially repeated segments give to the body. The body is composed of segments which are usually of similar structure internally as well as externally.
3. Presence of cuticles secreted by the underlying epidermis containing unicellular gland cells and sensory cells.
4. Appendages unjointed and are minute, rod-like, chitonous setae, few to many per somite generally absent in *Hirudinea.*
5. Body wall consists of layers of circular and longitudinal muscles.
6. Coelom well developed, extensive, separated into segmental compartments by transverse partitions, or septa, but coelom is reduced in *Hirudinaria.*
7. The digestive tract complete, tube like, extending entire length of body from mouth to anus.
8. A closed circulatory system of longitudinal blood vessels with lateral branches in each somite, blood plasma contains dissolved haemoglobin and free amoebocytes.
9. Respiration by epidermis, by gills in some tube dwellers.
10. Excretion by segmental paired nephridia, each removing wastes from the coelem and blood stream directly to the exterior.
11. Nervous system with ventral nerve cord composed of paired ganglia at segmental intervals connected anteriorly with the dorsal "brain" by a pair of circumpharyngeal connectives.
12. Sensory organs in the form of sensory cells, organs for touch, taste and light perception are present.
13. In few the sexes are separate, while in others sexes are united (hermaphrodite).
14. Gonads may be simple structure as in *Nereis,* where they develop only during breeding season. In some forms gonads are well developed.

15. Cleavage is spiral and determinate.
16. Development direct or indirect through a larval stage, the *trochophore*.
17. Process of regeneration is common.

CLASSIFICATION

There are about 8,700 known species of segmented worms which are divided into four main classes. The classification is primarily based on the basis of presence or absence of setae, parapodia and metamerism. The 4 classes are:

Class - I. Polychaeta

Class - II. Oligochaeta

Class - III. Hirudina

Class - IV. Archiannelida.

Class. I. Polychaeta

(Gr. *poly* = many; *chaete* = bristles)

1. These are marine and carnivorous annelids.
2. Body usually elongated, cylindrical and distinctly segmented into numerous similar metameres.
3. Head consists of prostomium and peristormium and bears eyes, tentacles, cirri and palps.
4. Setae are numerous and are borne up on leteral prominences of the body wall known as parapodia.
5. Clitellum is absent.
6. Parapodia highly vascular and respiratory in function.
7. Coelom is specious usually divided by intersegmental septa.
8. The blood vascular system is well-developed and does not communicate with coelom.
9. Alimentary canal is provided with an eversible buccal region and protrusible pharynx.
10. Sexes are separate. Gonads are simple and developed by active proliferation of coelomic epithelium.
11. Fertilization external, free-swimming trochophore larva.
12. Asexual reproduction by lateral budding.

Class Polychaeta is divided in two orders:

Order (i) Errentia

1. Free swimming, often pelagic while some are tubicolous (live in tubes).
2. All segments are similar except head and regions.
3. Parapodia provided with cirri, are equally developed throughout. These are organs of locomotion.
4. The head is usually definite which bears eyes, tentacles and cirri.
5. Pharynx is usually protrusible and armed with chitinous jaws and teeth.
6. Clitellum absent.
7. The branchiae or gills are present but not restricted to anterior end of body.

   Examples: *Aphrodite, Polynoe, Nereis, Glycera, Eunine, Syllis.*

Order (ii) Sedentaria

1. Sedentary in habit. Burrowing and tube dwelling.
2. Body is distinguished into two or three regions due to differences in shape of segments, parapodia and setae.
3. Head is small or much modified, without eyes and tentacles, prostomium indistinct.
4. Gills are situated only in the anterior part of the body, when present.
5. Pharynx is non-protrusible devoid of jaws or teeth. Feeding on plankton or organic detritus.
6. The parapodia are peculiar which are confined in the posterior region of body and without cirri.

   Examples: *Chaetopterus, Sabella, Arenicola, Terebella, Amphitrite, Serpula, Spirobis.*

Class. II. Oligochaeta

(L., *oligos* = few; *chaete* = bristles)

1. Mostly terrestrial, some live fresh-water.
2. Body with conspicuous external and internal segmentation.
3. Head not distinct, prostomium is usually small, without eyes and tentacles.
4. Parapodia and cirri are absent. Setae are usually arranged segmentally.
5. Clitellum usually present.
6. Pharynx is not protrusible and without jaws.
7. Hermaphrodite i.e. bisexual. Gonads are complicated. Overies and testes are compact structures.
8. Development direct without larval stage.

Class Oligochaeta is divided in two orders:

Order (i) Archioligochaeta

1. Mostly fresh water forms.
2. Body has few segments. Setae present.
3. Gizzard is either absent or poorly developed.
4. Simple clitellum, consists of single layer of cells situated for forwards.
5. Eye spots are usually present.
6. Reproduction is both asexual and sexual.
7. Male reproductive openings lie in front of female reproductive openings.

   Examples: *Tubifex, Actosoma.*

Order (ii) Neooligochaeta

1. Mostly terrestrial forms found in moist soil.
2. Body is large with many segments.
3. Setae are arranged in lumbricine manner.
4. Well developed gizzard.
5. Clitellum after 12th segment and is composed of two or more layers of cells.

6. Female genital apertures before male genital pore and usually lie in 14th segment.
7. Eye spots are developed.
8. Reproduction sexual only.
9. No free larval stage.

   Examples: *Pheretima, Lumbricus, Megascolex, Eutypheus.*

Class III. Hirudinea

1. They are marine, aquatic, terrestrial or free living. Some are ectoparasitic and blood-sucking annelids.
2. Body is segmented and is marked externally by ring-like annuli.
3. Presence of anterior and posterior cup-shaped suckers which are the organs of adhesion and locomotion.
4. The ventral mouth lies in the cup-shaped hollow cavity of anterior sucker. The anus is dorsal and situated just above the posterior sucker.
5. The coelom is greatly reduced due to the presence of connective tissue and is represented by haemocoelomic sinuses.
6. The true blood vessels with definite muscular walls present.
7. The nervous system includes a brain united by small oesophageal connectives to a double ganglionated ventral nerve cord.
8. Nephridia are segmentally arranged and open independently to exterior by nephridiopore, which are the organs of excretion.
9. Hermaphrodite, the testes are many and segmentally arranged, whereas ovary is single paired. Eggs are laid in cocoons.
10. Fertilization internal, development direct without larval stage.

Class Hirudinea is divided into following orders:

Order (i) Acanthobdellida

1. Mostly ectoparasite on the fin of salmon fishes.
2. Anterior sucker wanting, posterior sucker well formed.
3. Proboscis is small and not well developed.
4. Nephridia without internal openings.
5. Body generally composed of twenty or twenty-one segments.
6. It forms a connecting link between Oligochaeta and Hirudinea.

   Example: *Acanthobdella.*

Order (ii) Rhynchobdella

1. Aquatic leeches, parasite on snails, frogs and fishes.
2. The anterior part of body may be protruded and retracted so as to form a proboscis or introvert. Jaws are absent.
3. Each typical body segment consist of 3, 6 or 12 rings.
4. The mouth is minute slit-like opening placed inside the anterior sucker.
5. Blood is colourless. Coelom is reduced to sinuses without botryoidal tissues.

   Examples: *Branchellion, Glossiphonia, Pontobdella, Piscicola.*

Order (iii) Gnathobdella

1. Fresh water and terrestrial forms. Ectoparasites and blood sucking.
2. Each typical segment consists of five rings or annuli.
3. Anterior sucker has three jaws, one median dorsal and two ventro-lateral.
4. Proboscis non-protrusible or absent.
5. Blood is red in colour.
6. Coelom is reduced. Botryoidal tissue present.

   Examples: *Hirudo, Hirudinaria, Haemopis, Aelostoma.*

Order (iv) Pharyngobdella

1. Freshwater amphibious carnivorous leeches.
2. Each body segment is divided into five rings or annuli.
3. Pharynx non-protrusible. Jaws are absent.

   Examples: *Dina, Erpobdella, Trocheta.*

Class. IV Archiannelida

1. This group represents the primitive members of Annelida.
2. Mostly marine worms.
3. Body is elongated; cylindrical with internal segmentation.
4. The head is distinct bearing the tentacles, eyes and ciliated pit.
5. Parapodia are wanting.
6. Hermaphrodite or unisexual; gonads are simple and develop temporarily only during breeding season by active proliferation of colomic epithelium.

   About 45 species, one dozen genera are included in this class. The class is divided into five families.

   (i) Polygordidae *e.g. Polygordius, Protannelis.*

   (ii) Protodrilidae *e.g. Protodrilus.*

   (iii) Saccocirridae *e.g. Saccocirus.*

   (iv) Dinophilidae *e.g. Dinophilus, Diurodrilus, Trilebodrilus.*

   (v) Nerillidae *e.g. Nerilla, Nerillidium, Troglochaetus.*

POLYNOE

Phylum	-	Annelida
Class	-	Polychaeta
Order	-	Errantia
Genues	-	*Polynoe*

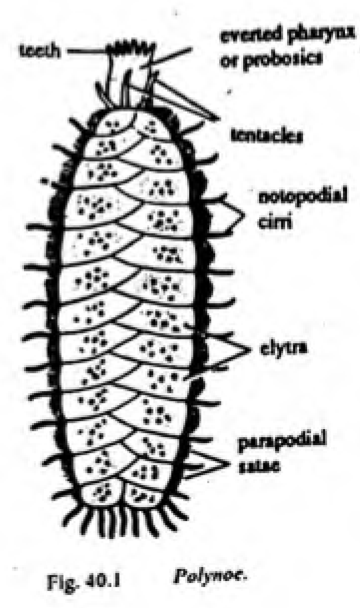


Fig. 40.1 *Polynoe.*

1. It is a bioluminescent polychaet found under stones in sea-water near tide mark.

2. It is found in U.S.A. (South Carolina to Massachusetts) and Europe.
3. Body is short, broad and oval with few segments. Body shows considerable degree of dorso-ventral compression.
4. It has a covering of elytra which are modified dorsal cirri. Elytra do not contain setae and have rich nerve supply.
5. Elytra are bioluminescent and the illuminating elytra are cast off when distrubed or elytra are shed-off to deceive the enemy.
6. Head bears three tentacles and two pairs of peristomial cirri.
7. Pharynx is protrusible.
8. It is carnivorous and may even eat each other (cannibalism).
9. Fertilized eggs and resulting embryos adhere in masses to the dorsal surface under the shelter of elytra.

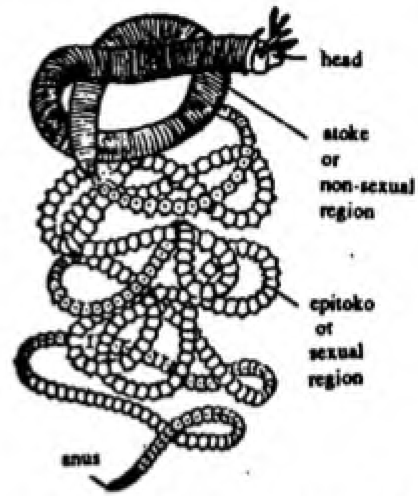


Fig. 40.2 The Pacific palolo worm, *Eunice viridis*.

EUNICE

The classification is same as that of *Polynoe.*

1. It is tube-dwelling marine polychaete found among the coral reefs at sea-bottom.
2. It is found in Atlantic and Pacific oceans, West Indies and Fiji Islands.
3. It is commonly known as 'palolo-worm'.
4. Body elongated with numerous segments. Prostomium consists of two segments with one pair of cirri, five tentacles and a large palp.
5. Gills begin usually on 6th segment.
6. Body yellowish or brownish and differentiated into anterior sexless *atoke* and posterior sexual *epitoke* regions. Epitoke projects from the tube and gets separated from atoke, and come to the surface, swim vigorously and finally discharge the gonads. The empty epitoke sinks to the bottom after swarming.
7. Fertilized eggs develop into a larval form.

SYLLIS

The classification is the same as that of *Polynoe.*

1. *Syllis* is a pelagic, marine polycheat.
2. *Syllis* is common in U.S.A., Woods Hole regions, Long Island, Sound to Bay of Fundy.
3. Small elongated worms, less than an inch in length.
4. Head small with prostomium and peristomium.
5. Prostomium with eyes, three tentacles and two fused palps.
6. Peristomium carries two pairs of cirri, tentacles and cirri are fused.
7. Each segment of the body carries a pair of parapodia.

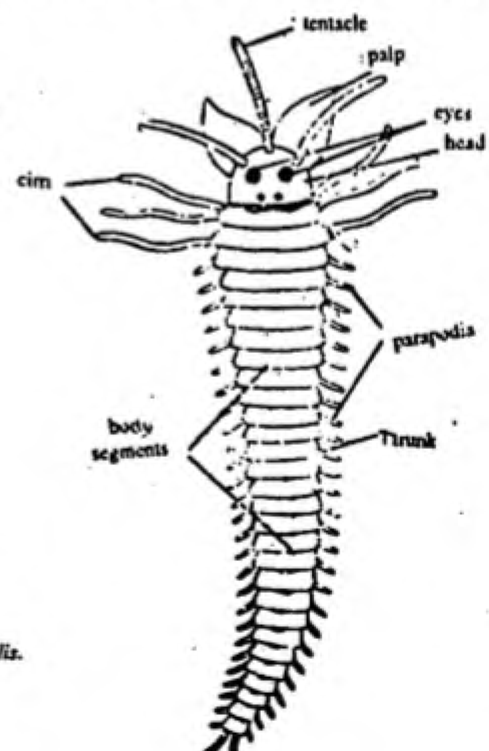


Fig. 40.3 *Syllis.*

8. Parapodia without notopodium, represented by long jointed notopodial cirrus.
9. Neuropodium with setae and cirrus.
10. The pharynx has a single large tooth provided with a poison gland opening near its apex.
11. A muscular proventriculus generally present.
12. Asexual reproduction by lateral branching, fission and gemmation is common.
13. Sexual reproduction with alternation of generations.
14. The sexual forms develop from ovum and asexual forms develop by process of posterior constriction and proliferation.
15. The sexual forms detached from the colony and help in dipersal of the species.

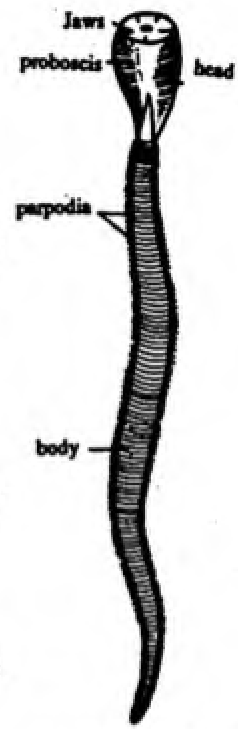


Fig. 40.4 *Glycera.*

GLYCERA

The classification is the same as that of *Polynoe.*

1. It is a marine polychaet living in a cylindrical burrow which is made by the proboscis in the sand, mud, in shallow water.
2. It is found in U.S.A., North Carolina to Bay of Fundy and South Carolina to Cape Cod.
3. The body of *Glycera* is elongated, cylindrical and meta merically segmented.
4. The head is distinct bearing a small conical prostomium with minute tentacles and rudiment palps.
5. The parapodia are small out-growths of integument which contain special gills.
6. Presence of a long, tubular proboscis bearing teeth, which give the peculiar shape to the worm.
7. There are no blood vessels; each gill contains a diverticulum of coelom. However, the perivisceral fluid contains numerous red corpuscles which assume the function of blood.
8. It is generally used as a fishbait.

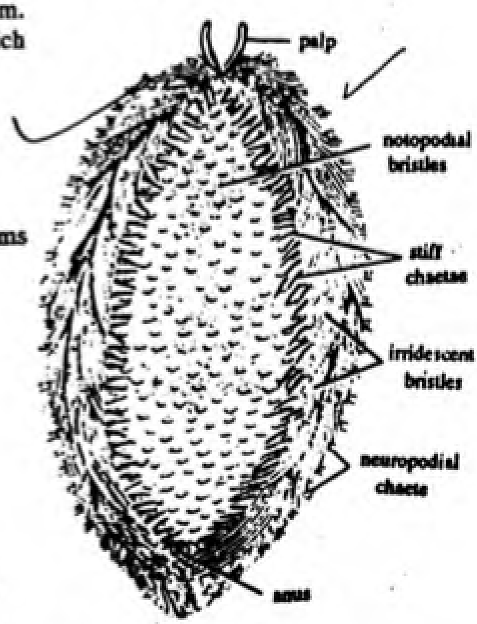


Fig. 40.5 *Aphrodite.*

APHRODITE

1. *Aphrodite* or sea-mouse commonly found in deep water 10 to 100 fathoms in muddy bottoms of almost all seas.
2. It generally burrows in mud and creeps on the sea bottom.
3. Fairly common in coral line.
4. It is commonly known as "sea mouse".
5. Body short almost oval and dorso-ventrally compressed.
6. Head small generally hidden, situated at the anterior end.
7. The head carries a single median tentacle and two large lateral palps.
8. Body is covered by modified dorsal cirri the elytra, which are plate like.
9. The elytra is a respiratory organ.
10. Many of the notopodial chaetae are iridescent forming a blanket of felt-like covering of the whole body of animal.

11. Apart from these brilliantly coloured thread-like setae three are spine-like brown stiff bristles.
12. The anus is situated at the extreme posterior end on the dorsal surface.
13. When distributed the stiff irdiscent bristles can be erected just like the spine of porcupine to frighten away the enemies.
14. The alimentary canal has caeca for the digestion of food.
15. When animal moves in water it shows beautiful iridescent colour.

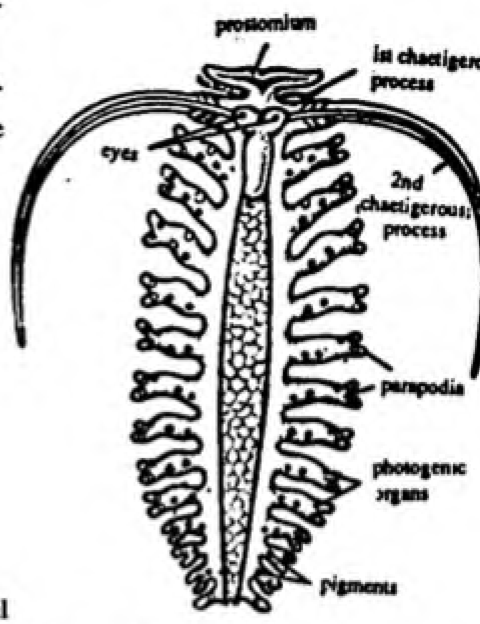


Fig. 40.6 *Tomopteris.*

TROMOPTERIS

The classification is the same as that of *Polynoe.*

1. It is a marine pelagic polychaete.
2. It is found in U.S.A. and Europe.
3. Body is colourless, transparent, having 18-20 segments.
4. Parapodia are large, bilobed and without setae.
5. Each lobe of parapodia bears a yellowish rosette-shaped or spherical photogenic organ.
6. The head is distinct due to the presence of hammer-shaped prosomium which contains a pair of eyes and two pairs of chaetigerous processess or tentacular cirri. The anterior are very short while posterior ones are very much elongated.
7. The ventral mouth is without jaws.
8. Circulatory system is absent.

MYZOSTOMA

The classification is the same as that of *Polynoe.*

1. It is an unsegmented, flatenned polychaete, generally ectoparasites on the starfishes, sea-lilies or feather stars.
2. They are found in West Indies, Havana, Europe.
3. These are disc-shaped situated on convex ventral side of the host.
4. Five pairs of parapodia situated on convex ventral side.
5. It has four pairs of small suckers, probably sense organs, on ventral side.
6. Ten pairs of minute protuberances of short cirri extend from the edge of the body.
7. Mouth is ventral in position that leads into a protrusible pharynx.
8. A distinct head is absent.
9. Coelom or body cavity is absent.
10. Circulatory system and respiratory organs are absent.

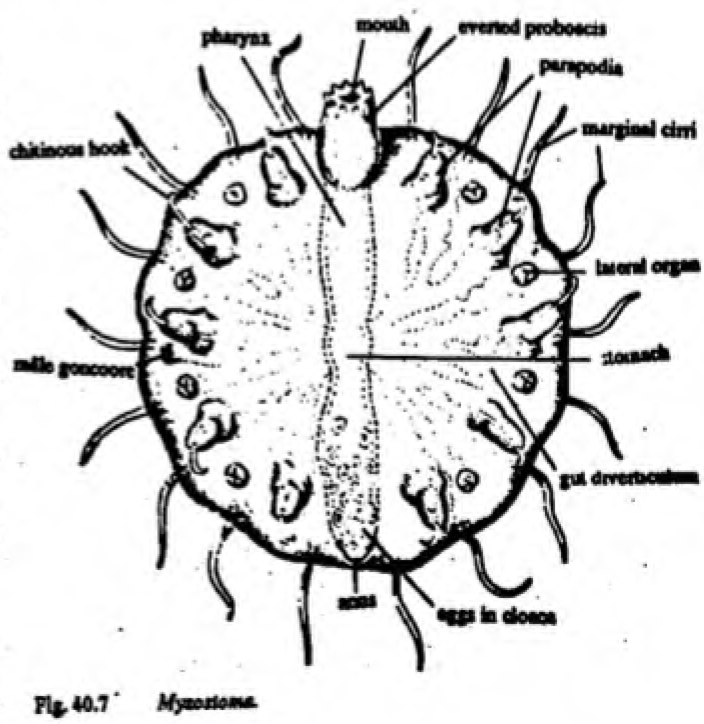


Fig. 40.7 *Myzostoma.*

11. Hermaphrodite, protandrous. Later testes degenerate leaving behind female reproductive organs.
12. Development indirect through trochophore larva.

CHAETOPTERUS

Phylum	-	Annelida
Class	-	Polychaeta
Order	-	Sedentaria
Genus	-	*Chaetopterus*

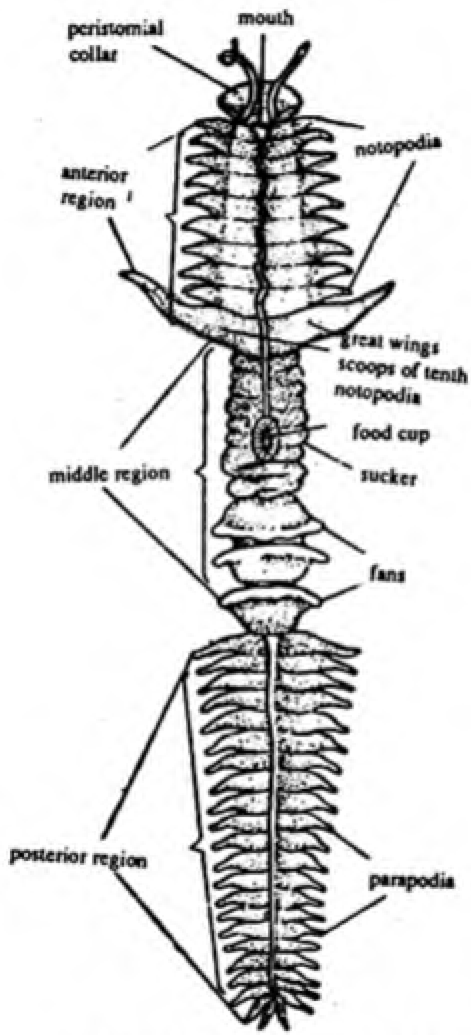


Fig. 40.8 *Chaetopterus*. Entire worm.

1. It is a tubicolous worm which generally lives permanently in a 'U' tube, made up of sand and mucous with excurrent and incurrent openings.
2. It is found in Europe, U.S.A., North Carolina to Cape Cod.
3. It is commonly known as 'paddle-worm'.
4. Long worms, about 0.15 to 0.45 metre in length.

5. Body divided into three regions:
   (a) Anterior flattened region with a funnel-shaped peristomial collar having two tentacles called peristomial cirri. In the 4th segment setae are enlarged, while 10th segment has a pair of wing-like aliform notopodia.
   (b) Middle region possesses modified parapodia forming three pairs of fans. It consists of 5 segments.
   (c) Hinder or posterior region has smaller segments bearing parapodia. These segments are about 30 in number.
6. Feeding is very characteristic. Three paired fans of middle region and cilia of ciliated groove create a water-current, which flows from one end of the tube to the other. The water-current serves for nutrition and respiration. Notopodia secrete mucus, which forms mucous begs with food particles. It is rolled into a ball or bolus which is passed on to the mouth through dorsal groove.
7. *Chaetopterus* is highly bioluminescent emits blue-green light.
8. A great power of regeneration, the whole body can be regenerated from a single segment.

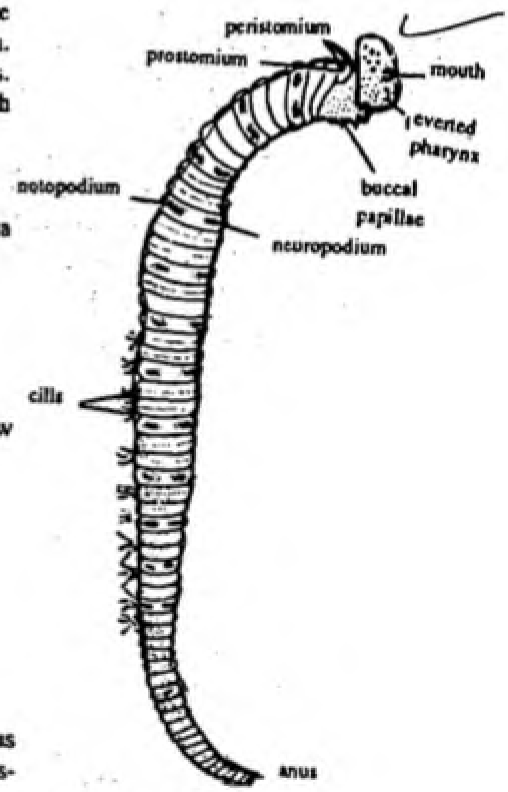


Fig. 40.9 *Arenicola.*

ARENICOLA

The classification is the same as that of *Chaetopterus.*

1. It is found on coasts between tide marks. It lives in a 'U' shaped burrow made up of sand and mucous.
2. It is found in Europe and U.S.A. (from Florida to Cape Cod).
3. It is popularly known as 'lug worm'.
4. The body is elongated, worm-like, broadest at anterior end.
5. The length of the worm is 5 to 8 inches.
6. The body is divided into three regions.
7. The anterior or prebranchial region of the peristomium, an achaetous segment and six chaetiferous segments. Eyes, tentacles absent. Peristomium contains 9 pairs of lithocytes.
8. The middle region not so thick of 12 or 13 chaetiferous and branchiferous segments.
9. The posterior region much thinner without setae and branchiae, with segments less clearly marked and variable in number.
10. Mouth lies ventral to the prostomium. The buccal region and pharynx protrusible as proboscis which is covered by chitinized papillae.
11. Nephridia six pairs.
12. It is generally used as bait for fishes.

AMPHITRITE

The classification is the same as that of *Chaetopterus.*

1. It is a tubicolous marine worm, living in tubes or burrows lined with sand and mucous.
2. It is found in Europe and U.S.A. (from North Carolina to Cape Cod).

3. Body elongated and cylindrical, pinkish in colour measuring about 20-30 cm in length.
4. Body is differentiated into three district regions: anterior region (head), middle region (trunk) and posterior region (abdomen).
5. Head small; prostomium and peristomimum are fused to form a horse-shoe shaped preoral lobe.
6. The prostomium forms the upper lip of and peristomium lower lip of the mouth. Eyes and palps are absent.
7. A tuft of long, yellowish and contractile tentacular filaments arises from a transverse ridge just behind the pre-oral lobe.
8. Tentacles are feeding organs bearing ciliated groove on its oral surface.
9. The first three segments of thorax bear red and feather-like branched gills. Rest of the segments bear notopodia with setae. Some of the thoracic segments have shield glands for mucous secretion.
10. Abdomen is long and many segmented. Each segment contains notopodia and neuropodia.

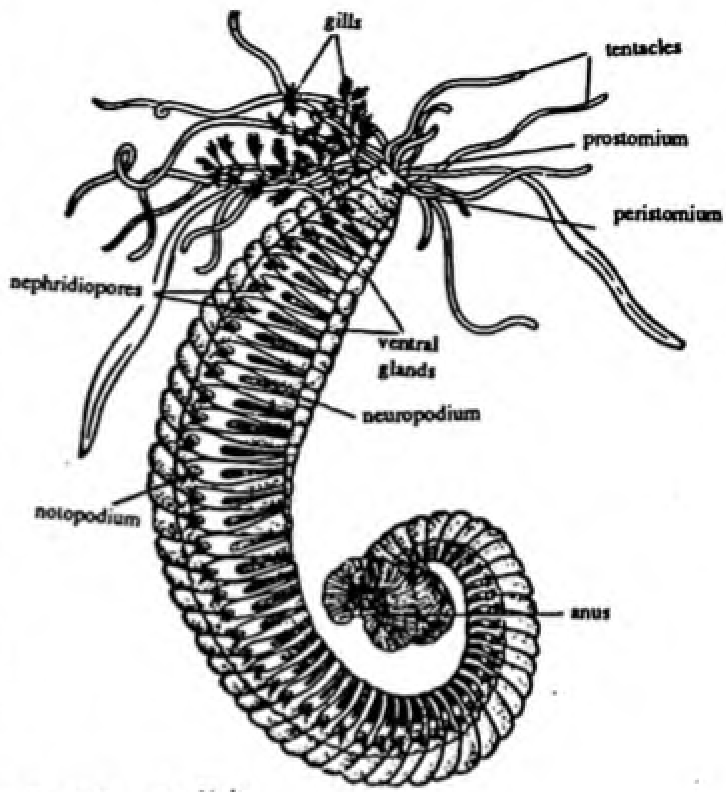


Fig. 40.10 *Amphitrite.*

11. The caudal segments lack notopodia and anus is found terminally in the last segment.

SERPULA

The classification is the same as that of *Chaetopterus.*

1. *Serpula* is a tubiculous worm, generally lies in tubes formed of mucin hardened with calcarous matter.
2. The tubes are generally 1.50 inches long.
3. Found in Europe and U.S.A. and commonly called 'fan-worms'.
4. The worm is minute with small trunk and abdominal segments.
5. The prostomium carries a pair of large semi-circular feathered gills which are modified palps.
6. The gills are respiratory and also serve as food collecting organs.
7. One of the tips of gill filament is modified into stopper or operculum which lock the aperture of tube when *Serpula* withdraws inside the tube.
8. The dorsal and ventral cirri of thoracic segments are fused to form a thoracic membrane on each side which is used to smoothen the interior of the tube.
9. The nephridia of posterior segments act as genital ducts.

Fig. 40.11 *Serpula.*

SABELLA

The classification is the same as that of *Chaetopterus.*

1. Tubicolous polychaetae, live in tubes of sea-mud or sand which they rarely or never leave.
2. It is distributed throughout the world but especially U.S.A. (North carolina to Cape Cod).
3. It is commonly called as 'peacock-worm'.
4. Body is elongated bearing equal number of segments.
5. Body is divisible into a small head, thorax and abdomen.
6. Head consists of prostomium with several large gill-filaments or feathery tentacles which are modified palps. Each tentacle has two rows of small pinnules having mucous secreting cells.
7. Thorax formed of 8 segments and provided with gland-shields and parapodia. The gland secrete mucous. The first segment is called peristomium which is collor-like and has notopodium and setae but no neuropodium.

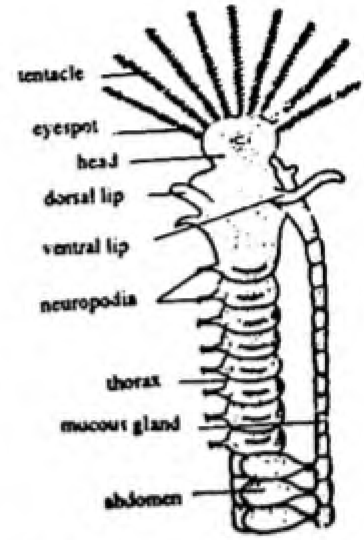


Fig. 40.12 *Sabella.*

8. Abdomen is formed of 300 segments, and is marked with a faecal groove which serves to carry faeces out of the tube.
9. Buccal mass is not eversible.
10. Eyes are present on branchial filaments.
11. *Sabella* is a filter-feeder, feeding by the movements of tentacles.

SPIRORBIS

The classification is the same as that of *Chaetopterus.*

1. It is a minute tubicolous, sedentary polychaete, living in a small calcareous tube, coiled in a flat spiral manner.
2. It is commonly found in U.S.A., Long Island to Bay of Fundy and northwards.
3. Body measure 3mm in length.
4. The body is cylindrical, elongated and is divisible into upper thorax and lower abdomen.
5. Each gill consists of an elongated stem on which are borne the short filaments; one of the gill filaments is enlarged to form an operculum which closes the mouth of tube.

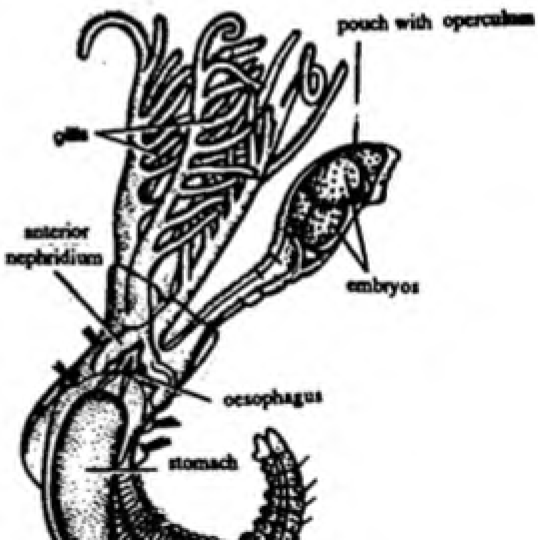


Fig. 40.13 *Spirorbis.*

6. The animal is hermaphrodite: anterior part of body gives rise to the ova while posterior part or abdomen produces the sperms.
7. Eggs are developed inside the operculum.
8. The prostomium and peristomium are compactly fused together to form a collar which secretes the tube.
9. Presence of paired anterior nephridia which are excretory in function.

STERNEASPIS

The classification is the same as that of *Chaetopterus.*

1. It is a marine, tubicolous polychaete.
2. It is found in U.S.A. (Florida).
3. The body is short, broad and made up of about 30 segments.
4. Head is formed of prostomium and peristomium.
5. Prostomium is elongated and without any appendages.
6. Peristomium is knob-like and contains mouth.
7. First three segments possess incomplete bristles, segments 8th-15th possess setae while segments 5th, 6th, 7th and 16th - 24th are without setae.
8. Intestine is coiled.
9. Anus is terminal and surrounded by gills.
10. Presence of a single pair of nephridia bearing small ciliated funnels, which do not open to exterior.
11. A ventral shield formed by a thickening of the cuticle in the posterior region of the body bears a number of setae around its edges.

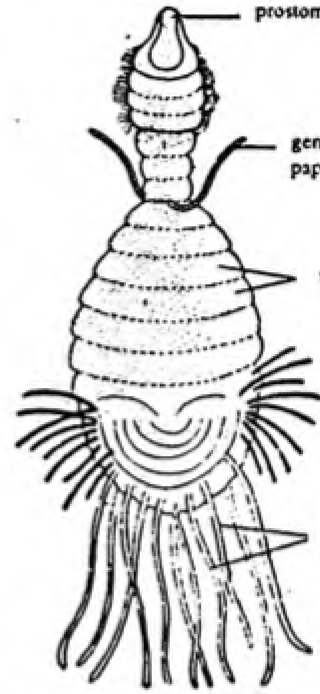


Fig. 40.14 *Sternaspis.*

TERЕBELLA

The classification is the same as that of *Chaetopterus.*

1. It is a marine, burrowing, sedentary polychaete.
2. It is found in Europe, U.S.A., Woods-Hole region and Vineyard Sound to Bay of Fundy.
3. Body is long and vermiform differentiated into head, thorax and abdomen.
4. Head is horse-shaped made up of prostomium and peristomium.
5. Prostomium flatenned into a mobile upper lip which carries a transverse series of numerous filiform tentacles and two pairs of eyespots. Palps are absent.
6. Peristomium forms lower lip and lacks cirri.
7. The gills or branchiae are found on the dorsal surface of few anterior segments and they form four wide comb-like branches on a single peduncle.
8. Thorax with gland shields.
9. Parapodia are feebly developed.
10. Nephridia are large and small and serve as both excretory and genital ducts.

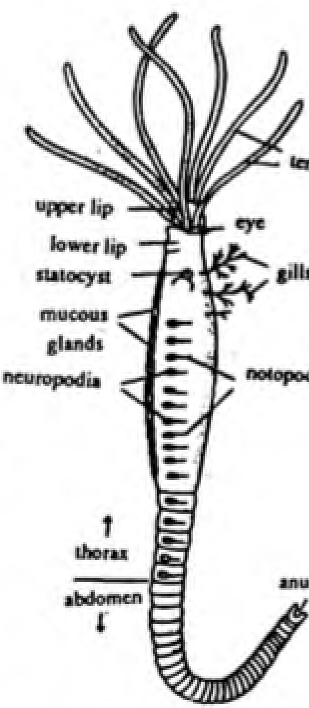


Fig. 40.15 *Terebella*

MYXICOLA

The classification is the same as that of *Chaetopterus*.

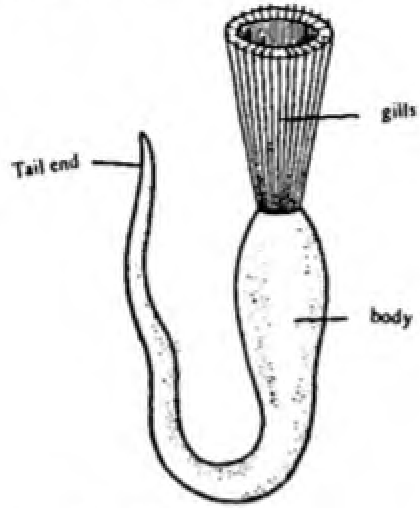


Fig. 40.16 *Myxicola.*

1. *Myxicola* is a sedentary tubicolous animal lives in a tube in the sea sand. Occasionally the worm leaves the tube and swims freely.
2. Body is elongated, dark green in colour and measures about 10 cm in length.
3. Eyes, mucous and shields are absent.
4. Gills are present which are well developed and protrudes out.

AEOLOSOMA

Phylum	-	Annelida
Class	-	Oligochaeta
Order	-	Archioligochaeta
Genus	-	*Aeolosoma*

1. It is a freshwater worm found in ponds, pools and living among the algae.
2. Body transparent and dorso-ventrally flatenned and spotted with red, green or yellow oil globules in the integument.
3. Body is made up of 7-10 segments, which are not clearly marked. Coelomic septa are absent.
4. Prostomium ciliated ventrally and bears a pair of ciliated pit.
5. Each segment bears four bundles of hair-like setae.
6. Clitellum present only on the ventral side of the 5th - 7th segments.
7. Nephridia are paired and metamerically repeated.
8. Nervous system is hypodermis, the ventral nerve cord is absent.

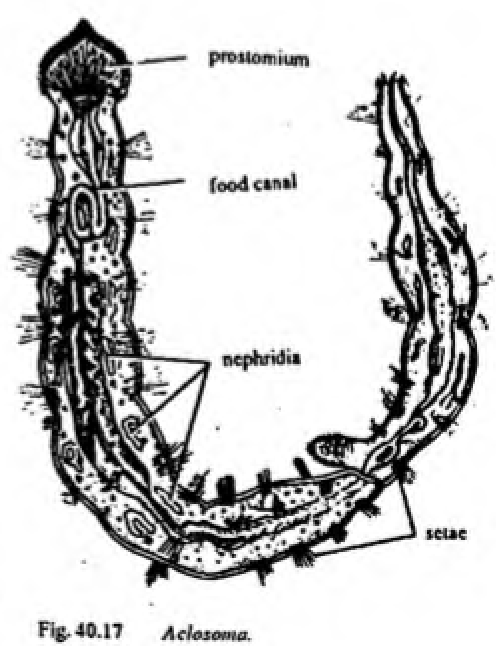


Fig. 40.17 *Aelosoma.*

9. These are hermaphrodite worms but commonly reproducing asexually by transverse fission.
10. Nephridial ducts act as gonoduct. The genital products pass out through nephridiopores.

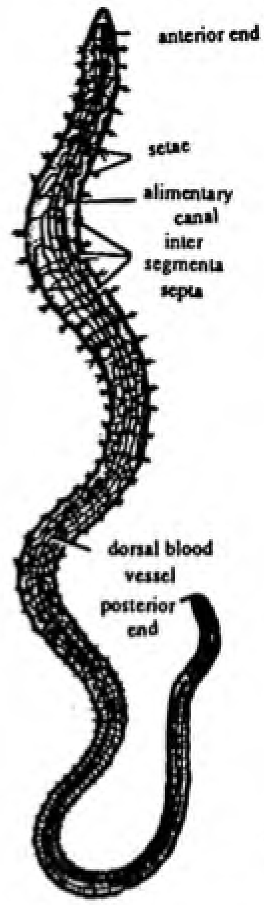


Fig. 40.18 *Tubifex.*

TUBIFEX

The classification is the same as that *Aelosoma.*

1. It is a tubicolous fresh water animal found on the bottom of deep lakes. It lives into tubes, made up of mud, minerals and mucous.
2. It is found in U.S.A. (Long Island Sound to Maine).
3. They occur in large numbers in the form of patches.
4. The body is elongated, somewhat cylindrical reaching upto the length of 4 cm. approximately.
5. It is reddish in colour and is divisible into a number of ring-like metameres.
6. Each segment of body except the few posterior segments bears the tufts of minute setae on its either side.
7. The posterior end of body protrudes out from the tube and waves back and forth.
8. The clitellum is found in 11th and 12th segment.
9. Contractile heart is present in 8th segment.
10. Male genital pore lies in the 11th segment and female genital pore in the 12th segment.
11. The eggs are deposited in coccon, which contain food yolk for the nourishment of embryo. The epibolic type of process occurs during development.

LUMBRICUS

Phylum	-	Annelida
Class	-	Oligochaeta
Order	-	Neooligochaeta
Genus	-	*Lumbricus*

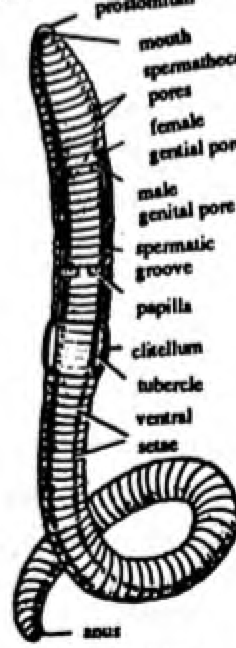


Fig. 40.19 *Lumbricus.*

1. It is found in moist soil (terrestrial).
2. It is a common earthworm of Europe and U.S.A.
3 Body is cylindrical, 15-30 cm in length and made up of 100-150 segments.
4. The lobular prostomium divides peristomium into two parts.
5. Clitellum present in segments from 32-37 and is swollen.
6. Each metamer except first and last, bears 'S' shaped chitinous chaetae arranged in 4 pairs of which two are ventral and two ventro-lateral.
7. Female and male genital pores are paired and are situated in 14th and 15th segments.
8. Gizzard is absent.

9. Prostate glands are absent.
10. Genital paillae absent.
11. There are two pairs of spermathecae in 9th and 10th segments. Three pairs of seminal vesicles in 9th, 11th and 12th segments. Testis sacs are two, one in 10th and other in 11th segment.
12. Each segment has a pair of nephridiopores, situated ventro-laterally.

MEGASCOLEX

The classification is the same as that of *Lumbricus.*

1. It is a terrestrial worm lives in moist soil.
2. It is found in South India, Sri Lanka, Australia, Tasmania and New Zealand.
3. It measures 8-12 cm in length and bears 80-100 segments.
4. The dorsal body surface is dark purplish brown and the ventral surface is somewhat pale in colour.
5. Clitellum present in segments from 14-17.
6. Gizzard lies in 6th segment.
7. Longitudinal blood vessels are two, dorsal and ventral and they are connected by eight pairs of hearts in segments 6-13.
8. One pair of metanephridia is present in each segment behind the 19th segment.
9. Two pairs of seminal vesicles, one pair lies in 9th segment and other in 12th segment.
10. One pair of prostate glands lie in segments 18 and 19.
11. 3 pairs of spermathecae lie in segments, 7, 8 and 9. Each with two diverticula.
12. Two female genital pores on segment 14th.
13. Two pairs of penial setae help in copulation.

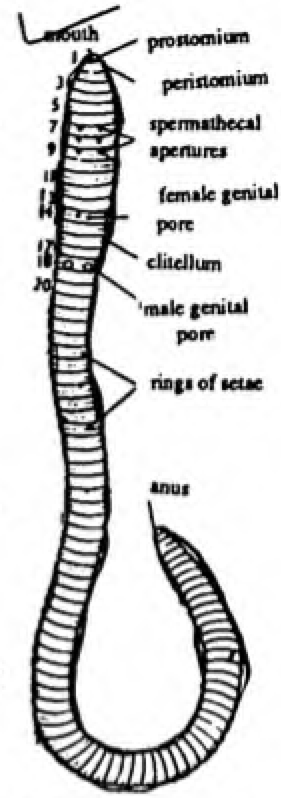


Fig. 40.20 *Megascolex.*

ACANTHOBDELLA

Phylum	-	Annelida
Class	-	Hirudinea
Order	-	Acanthobdellida
Genus	-	*Acanthobdella*

1. It is an ectoparasite on the caudal and anal fins of salmon fish.
2. It is found in West Siberia and North-East Europe.
3. Body is elongated dorso-ventrally flatenned and both the ends pointed.
4. It contains only 20 segments.
5. Anterior sucker is absent, posterior sucker made up of four segments.
6. First five segments bear double rows of setae ventro-laterally.
7. Body cavity or coelom spaceous and is incompletely divided by septa.
8. Nephridia with external and internal openings.

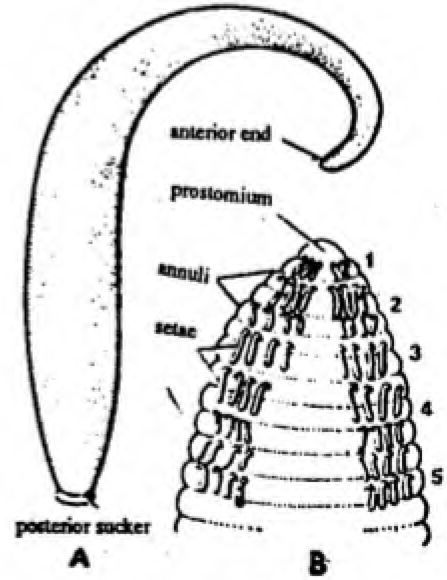


Fig. 40.21 *Acanthobdella.* A—Entire leech, B—Anterior end in ventral view showing setae.

9. Circulatory system made up of a dorsal and a ventral blood vessel.
10. Nervous system consists of 20 ventral ganglia.
11. Male genital pore in 7th segment and female genital pore in 8th segment.
12. *Acanthobdella* is a connecting link between Oligochaeta and Hirudinea.

PONTOBDELLA

Phylum	-	Annelida
Class	-	Hirudinea
Order	-	Rhynchobdella
Genus	-	*Pontobdella*

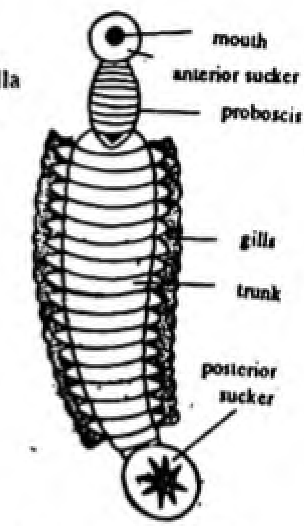


Fig. 40.22 *Pontobdella.*

1. It is an ectoparasite on fishes chiefly skates and rays. Sometimes it is called 'skate sucker'.
2. It is found in Europe and U.S.A.
3. The body is cylindrical, elongated with anterior narrow and posterior blunt portion.
4. The anterior and posterior suckers are cup-shaped and well marked.
5. Anterior sucker is applied to the skin of fish and then makes a wound.
6. The body surface is rough which is covered by small rounded green tubercles.
7. Nephridia form a complex network on the ventral surface of body.
8. The anterior end of body protrudes out to form a retractile proboscis or introvert.
9. Setae and jaws wanting.
10. Hermaphrodite, sexual reproduction is common.
11. Eggs are laid in molluscan shells. Parental care is shown as the eggs are guarded by the parent till they hatch.

BRANCHELLION

The classification is the same as that *Pontobdella.*

1. *Branchellion* is an ectoparasite on marine fishes specially *Torpedo.*
2. It is world wide in distribution but not reported in India.
3. Small, elongated body of about 10 cm. long.
4. The anterior end is produced into a proboscis and a wide abdominal region.
5. The abdomen bears 11 pairs of series of foliaceous non-digitate gills (branchiae) laterally in each segment.
6. The anterior and posterior suckers well developed and pedunculate.
7. Nephridia are absent but excretion by complex network of tubes.
8. Hermaphrodite, sexual reproduction is common.

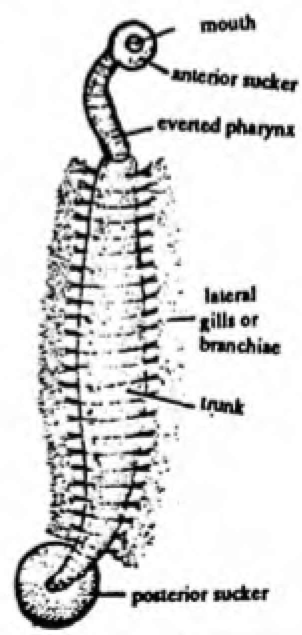


Fig. 40.23 *Branchellion.*

GLOSSIPHONIA

The classification is the same as that *Pontobdella.*

1. It is a freshwater leech found parasitic of mussels and feeds on *Chironomous* larvae.
2. It is world wide in distribution.
3. The body is broad and dorso-ventrally flattened. The anterior end tapers whereas the posterior part of body is oval.
4. Setae are wanting.
5. Three pairs of eyes persist.
6. The posterior sucker is cup-shaped and well formed.
7. Presence of elongated crop chambers arranged in the middle of body segments.
8. In this leech copulation has never been observed, but one individual deposits spermatophores on any part of the body of another individual.
9. The male and female ducts open by a common pore located between eleventh and twelth segments.
10. Cleavage unequal no cocoon formation takes place.

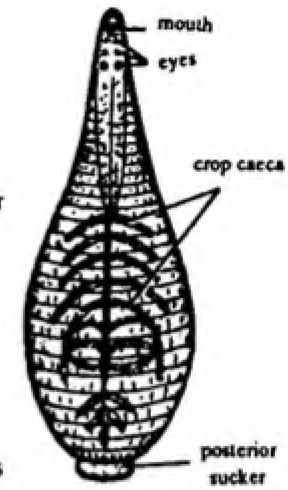


Fig. 40.24 *Glossiphonia*

OZOBRANCHUS

The classification is the same as that of *Pontobdella.*

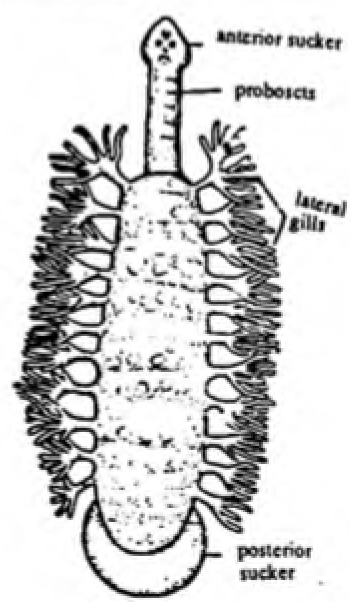


Fig. 40.25 *Ozobranchus.*

1. It is an ectoparasite on the river-turtle and fishes.
2. Body is sub-cylindrical that often bears lateral gills.
3. Usually more than three annuli per segment.
4. Anterior and posterior suckers are well developed.

5. Anterior region is produced into a long proboscis.

HERPOBDELLA (NEPHELES)

Phylum	-	Annelida
Class	-	Hirudinea
Order	-	Gnathobdellida
Genus	-	*Nepheles*

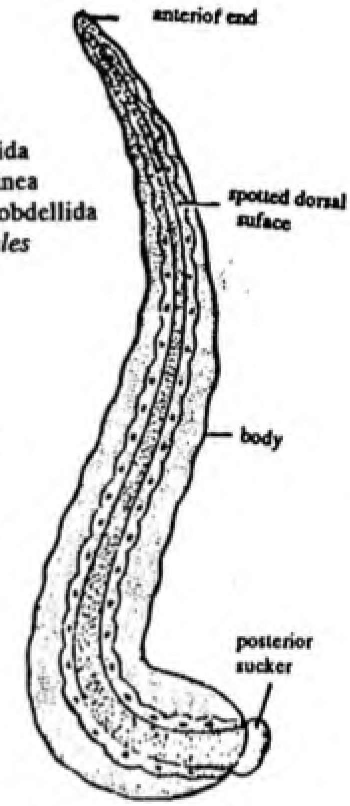


Fig. 40.26 *Nepheles.*

1. It is found in fresh water ponds and streams under stones and in vegetation.
2. It has world wide distribution.
3. Body is slender about 8 cm in length and brownish black in colour.
4. Anterior end is rounded and devoid of anterior sucker. Head bears 2 pairs of eyes.
5. Each body segment has 5 annuli. The annuli and true segments are not easily demarkated and consists of 19 segments.
6. Posterior end is flatenned and bears a distinct small posterior sucker.
7. Setae, parapodia and jaws are absent.
8. It is carnivorous, feeds on aquatic larvae, worms and snails.
9. Sexual openings are separated from one another by two rings.
10. Development takes place in cocoon.

HAEMOPIS

The classification is the same as that *Nepheles*.

1. It is found in ponds, streams and swampy meadows.
2. It is cosmopolitan in distribution.
3. It is commonly called 'hungry horse leech'.
4. Body segmented, segments indicated externally by ring-like constrictions, which are much more numerous than the true segments.
5. Head is not distinct, jaws are armed with blunt teeth in two rows. A pair of eyes present.
6. Presence of one pair of caeca in crop.
7. It is carnivorous leech, feeding on earthworms, aquatic larvae of insects, tadpoles and small fishes.
8. Copulatory glands are absent.
9. Development takes place in cocoons.

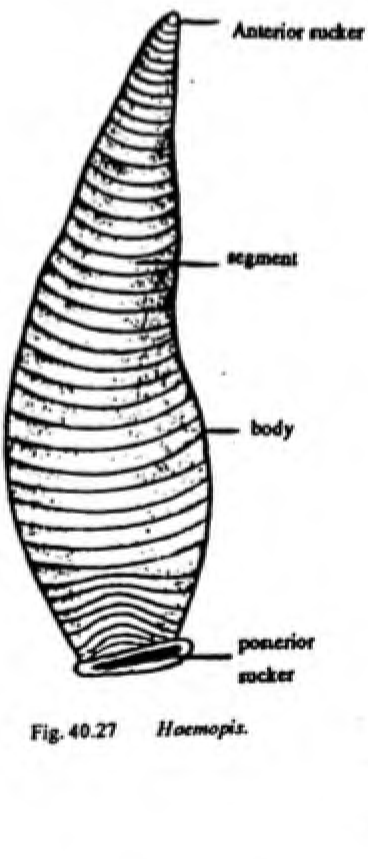


Fig. 40.27 *Haemopis.*

LIMANTIS

The classification is the same as that of *Nepheles.*

1. It is a fresh water ectoparasitic leech of domestic animal, horses, cattles etc.
2. Commonly found in Syria, Egypt and Lebanon.
3. Body is elongated never more than 4 mm in length.
4. Anterior and posterior suckers are well developed.
5. Proboscis non-protrusible.
6. Oral sucker armed with three jaws.
7. Each segment with 5 annuli.
8. Development is direct.

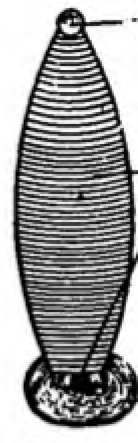


Fig. 40.28 *Limnatis.*

POLYGORDIUS

Phylum	-	Annelida
Class	-	Archiannelida
Genus	-	*Polygordius*

1. It is found living in the sand of European Seas.
2. *Polygordius* is a marine worm with narrow, elongated cylindrical body.
3. The prostomium is small, the peristomium large and forms the head, which bears paired prostomial tentacles and ciliated pits.
4. Presence of a tooth-like process round the anus, and in front a circlet of adhesive papillae.
5. Segmentation is not distinct in front, but well marked behind and is without parapodia or chaetae.
6. Beneath the skin longitudinal muscle fibres in four quadrants. Circular muscles absent.
7. Presence of paired segmentally arranged nepridia leading into nephrostomes.
8. Vascular system is reduced and single nerve cord lies in the epidermis.
9. Sexes are separate.
10. Gametes released by the rupture of the body wall.
11. Fertilization external. Development is indirect with Loven's larva, which resembles a typical trochophore larva.

Fig. 40.29 *Polygordius.*

PROTODRILLUS

The classification is the same as that of *Polygordius.*

1. It is small marine worm found in Inland Sea, Lake at Faro near Messina (U.S.A.)

Fig. 40.30 *Protodrilus.*

2. Body is narrow elongated and cylindrical.
3. Body segments are very indistinct and marked off by ciliated rings.
4. There is a median longitudinal groove on the ventral surface.
5. Body with small prostomium which bears cephelic tentacles and ciliated pits.
6. Anus is terminal surrounded by fin-like expansions.
7. The ventral nerve cords are fused.
8. Excretory system comprises paired segmental simple nephridia.
9. Hermaphrodite. Development is direct without larval stage and metamorphosis.

SACCOCIRRUS

The classification is the same as that of *Polygordius.*

1. It is marine worm found attached to sea-weeds by adhesive pad.
2. It is found in European countries and Madras.
3. Body long, cylindrical, 10-15 mm in length.
4. Anterior region bears a pair of cephalic tentacles and eyes.
5. Body segments marked by prominant inter-segmental grooves.
6. Each segment bears lateral setae.
7. Longitudinal ciliated groove is situated in the middle of ventral surface.
8. Anus terminal with adhesive pads on.
9. Nervous system comprises of two separate ventral nerve cords lying just beneath the epidermis.

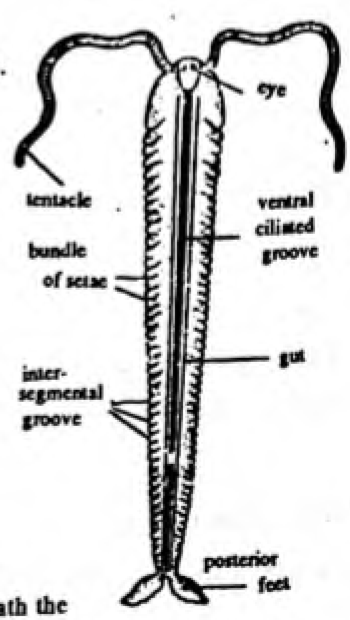


Fig. 40.31 *Saccocirrus.*

10. Sexes separate, female with spemathecae and males with a pair of protrusible penis in each segment.
11. Development is direct.

NERILLA

The classification is the same as that of *Polygordius*.

1. It is a marine worm found in sea-water.
2. Body elongated worm-like measuring 1 mm in length.
3. Head with three prostomial tentacles, two palps and two pairs of setae.
4. Sexes are separate.
5. Three genital segments in male and one in female.
6. In male three pairs of sperm ducts uniting at a common median genital aperture.
7. Development is direct.

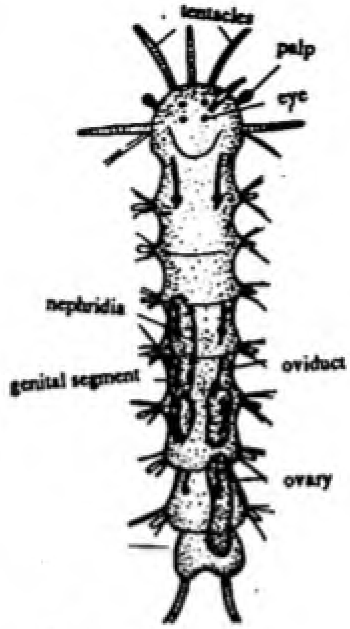


Fig. 40.32 *Nerilla.*

DINOPHILUS

The classification is the same as that of *Polygordius*.

1. *Dinophilus* is small, marine archiannelid, found among sea weeds.
2. Body short, flatenned looks like a planarian of about 2 mm long.
3. Body with 5 to 6 segments with ciliated ring.
4. The entire ventral surface is uniformly clothed with cilia.
5. Prostomium broad, with two eyes and ciliated pits.
6. Tentacles and palps are absent.
7. Coelom very much reduced with five pairs of nephridia. Sexes are separate.
8. Male with median penis.
9. Females with eggs of two sizes the smaller giving rise to males and the larger to females.

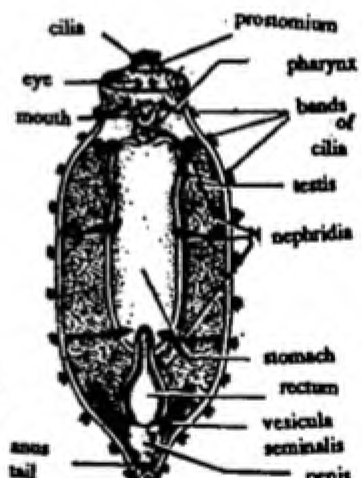


Fig. 40.33 *Dinophilus.*

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NEANTHES = NEREIS

Neanthes (old name *Nereis)* is commonly known as *'sandworm'* because it is found buried in sand or *'clamworm'* as it is found along with clams but has no ecological relationship with them. *Neanthes* is one of the largest and most common typical marine annelid with most of the characteristics of the phylum. It has a great number of species which are found in different parts of the world but resemble greatly with each other. Few important and common species are : *N. dumerilli, N. diversicolar, N. irrorata, N. cultrifera, N. virens, N. pelagica,*and *N. caudata.*

Fig. 41.1 *Neanthes.*

SYSTEMATIC POSITION

Phylum	-	Annelida
Class	-	Polychaeta
Order	-	Errantia
Genus	-	*Neanthes (Nereis)*

HABITS AND HABITAT

Neanthes has world wide distribution i.e. it is found throughout the world, in Europe, America , Alasks, North Pacific and other places. It inhibits the sea-shores between tide marks. It is also found among the sea-weeds and under stones, but normally it lives in burrows. The burrows are formed 60 cm deep. The burrow is lined by mucous which help in cementing the grains of sand, a mechanism by which the burrow cannot collapse. The worm lives within the burrow during day time. At night, it protrudes the anterior of its body and moves it all round in the search of food. Thus the worm is nocturnal. The worm is carnivorous in diet and feeds on small crustaceans, molluscs and annelids. Occasionally, the worm leave its burrow and creeps about the stones. During breeding season, it leaves its burrow permanently and swims about actively in the surface layer of water.

EXTERNAL MORPHOLOGY

Shape and size. Body is elongated, cylindrical and vermiform. It is bilaterally symmetrical, metamerically segmented and somewhat flattened dorsoventrally. It gradually tapers to the posterior end. the dorsal surface is convex but the ventral flat. The size varies from few to 40 cm.

Colouration. Different species are differently coloured. *N. virens* is steel-blue in colour; N. *limbata* is of brownish colour while jaws are light amber-coloured; N. *cultrifera* is greenish; N. *pelagica* is a raddish-brown; N.*lamnicola* is also raddish-brown; and N. *vexilosa* is dark brown or blue-green with iridescence.

Segmentation. Body is divided into approximately 200 or more *segments* or *metameres.* In N. *cultrifera* there are 80 segments. These are marked externally by grooves and internally by septa. All the metaneres are alike except the last which is

somewhat rounded. It is known as *tail somite* or *pygidium* and carries a pair of *anal cirri.* Anus is terminal.

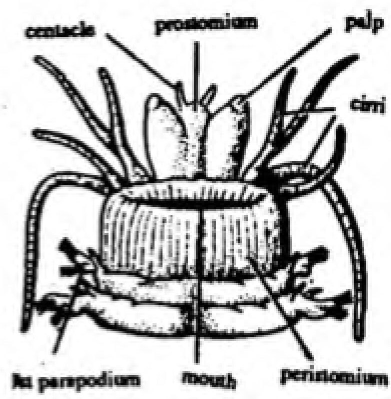

Fig. 41.2 *Neanthes.*

Divisions of the body. The whole body of *Neanthes* is divided into three well-defined regions.

1. Head
2. Trunk
3. Pygidium.

1. *Head*

The anterior-most part of the body is specialized into a head, which consists of two main part., *prostomium* and *peristomium.*

(i) *Prostomium* (Gr., *pro*=before; *stoma*=mouth). It is the part before mouth and is roughly a triangular lobe. It is situated mid-dorsally. Protruding forward from the anterior edge of the prostomium are two tentacles and from the ventral side project two *palpi.* Each palp is two-jointed. Tentacles are regarded as organs of touch, and palpi are organs of taste and smell. There are two pairs of simple eyes on the dorsal surface of the prostomium for the perception of light. On each side of prostomium is a ciliated pit, which is called *nuchal organ* considered to be a sense-organ of doubtful importance.

(ii) *Peristomium* (Gr, *peri*=around; *stoma*=mouth). It is a large ring-like round part present behind the prostomium. It bears on its ventral side a slit-like *mouth.* It differs from a trunk segment in being longer, in lacking *parapodia* and in the presence of four (two pairs) thread-like *peristomial cirri* on each side; of these one pair is dorso-lateral and the other ventro-lateral. These are homologous with the notopodial cirri and neuropodial cirri of the parapodia of trunk segments. Each cirrus is a long, slender, tactile structure, having a short proximal joint and a long distal joint. The dorsol cirri are longer than the ventral ones.

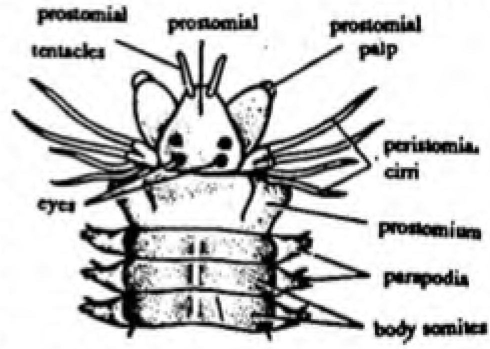

Fig. 41.3 *Neanthes.*

The study of the developmental stages of *Neanthes* shows that the prostomium is not a true segment of the body but develops as a dorsoanterior projection of the peristomium, whereas the peristomium is formed by the fusion of the first and second body segments.

2. *Trunk*

It comprises practically the entire body except the head and the last segment or pygidium. It comprises a number of segments which are all alike. Each trunk segment bears on either lateral sides a flat, fleshy, hollow and vertical flap-like structure, the parapodia. Term parapodia was coined by *Huxely*(Gr.*para*=besides; *podos*=foot)

It is a *biramous* structure and consists of an upper or dorsal part or *notopodium* and a lower or ventral part or *neuropodium.* Notopodium and neuropodium are both bilobed structures i.e. each part is further subdivided into two leaf-like lobes or *ligulae,* a dorsal *superior ligula* and a ventral *inferior ligula* and from each apperas a bundle of setae or chaetae. The setae lodged in an epidermel pit, the *setigerous sac.* Each seta develops from a single large formative cell, present at the base of setigerous sac. The setae can be protruded, rotated in all the directions and retracted by special muscles within the parapodia. Each set is two jointed structure with a proximal *shaft* and a distal blade. The setae are of two types (a) *Typical*

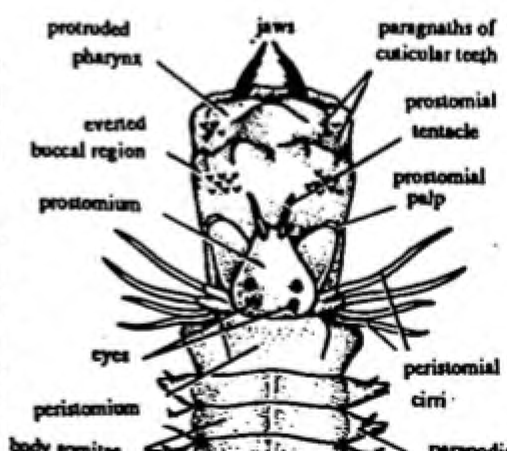

Fig. 41.4 *Neanthes.* Head in dorsed view with everted pharynx.

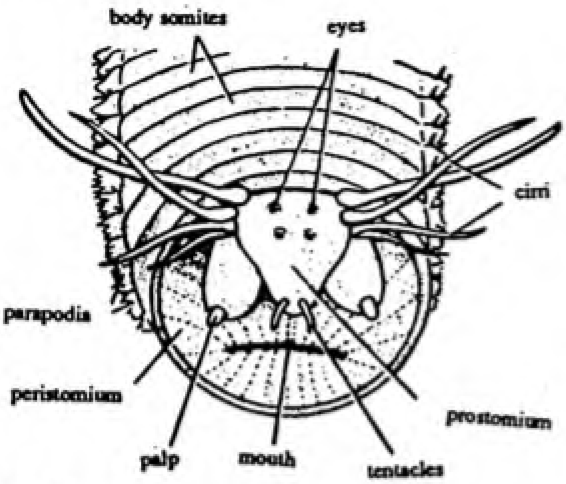

Fig. 41.5 *Neanthes*. Head in frontal view.

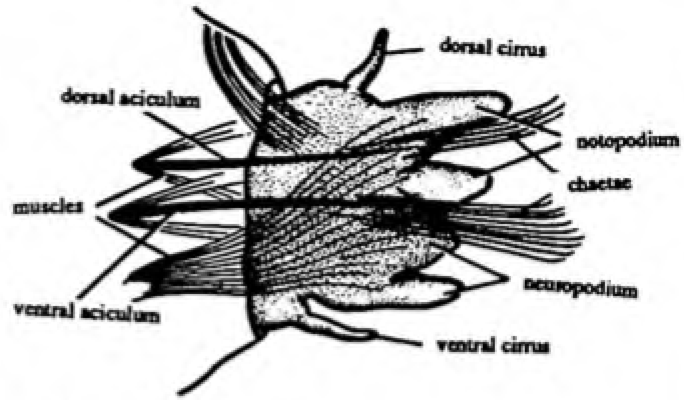

Fig. 41.6 *Neanthes*. Parapodium.

type has a long stout shaft and a short stout blade, (b) *Long blade type* has a small shaft but a long, pointed blade with one edge scratted. In Heteronereis phase a third type is also seen called as *oar shaped.* Here the blade becomes oar-shaped. Besides long setae in each part, there is a stouter, straight, dark-coloured seta known as *aciculum*, which projects only for a short distance but not beyond the outer edge of the parapodium. Setae help in locomotion, while *aciculum* has a skeletal function. The dorsal margin of notopodium is produced into a short, cylindrical tactile appendage the *dorsal cirrus* and a similar structure is produced at the ventral margin of the neuropodium, the *ventral cirrus.* Of the two cirri the dorsal one is much larger than the ventral.

The parapodia are the largest in the mid-region of the body and decrease in size towards the anterior and posterior ends of the body . The first two parts of parapodia have no notopodial setae. The parapodia are highly muscular and primarily the organs of locomotion, used both in creeping and in swimming. they are highly vascular and glandiular and probably also serve as respiratory organs.

Nephridispores. On the ventral side, near the base of parapodia, each segment bears a pair of minute excretory pores through which the nephriidia communicate out.

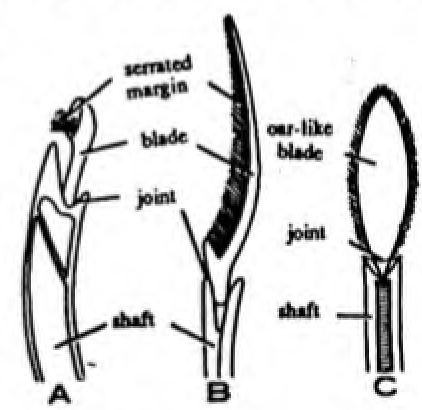

Fig. 41.7 *Neanthes*. Various of setae. A—Typical, B—Long blade, C—Oar shaped.

3. ***Pygidium or Tail***

The last segment is tail which bears a terminal anus, a pair of long filamentous *anal cirri* and several minute sensory papillae. This segment does not bear parapodia.

BODY WALL

The body wall consists of cuticle, epidermis, musculature and coelomic epithelium.

1. **Cuticle.** It is a thin, tough, chitinous and non-cellular layer covering the body externally. It is secreted by the epidermal cells underlying it. It is perforated by numerous pores through which the epidermal gland cells open out. The cuticle exhibits irridescent lusture due to the presence of two intersecting systems of fine striations in it.

2. **Epidermis.** It lies below the cuticle. It is made up of a single layer of columnar supporting cells resting on a basement membrane. Except the ventral side, the epidermis is thick at places. Many gland cells are found on the ventral surface near the base of parapodia. These gland cells secrete mucous which is used in forming the tubes in which the animal lives.

3. **Musculsture**. Below the epidermis are present the muscles which are of three types:

   (a) Circular, (b) longitudinal and (c) oblique muscles.

(a) *Circular muscles.* These from a continuous layer beneath the epidermis, which is slightly thicker on the ventral side. In the parapodia, the circular muscles are modified to form a complicated system of parapodial muscles comprising the *protractor* and *retractor* muscles. The protractors radiate from the bases of the setigerious sacs to the layer of circular muscles on all sides. The retractors extend from the outer part of the setigerious sacs to the dorso-laterial body wall. By the contraction of protractor muscles protrusion of acicula and central lobes of parapodia occur. The retractor muscles brings about withdrawl of the acicula-bearing lobes of the parapodia.

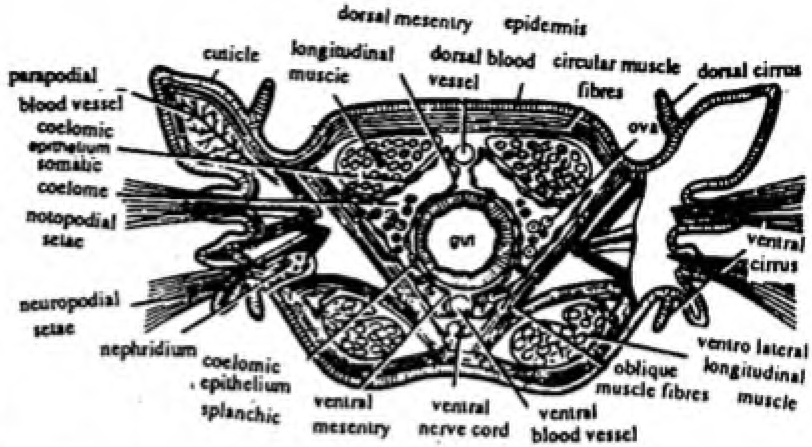

Fig. 41.8 *Neanthes.* T.S. of a segment with parapodia.

(b) *Longitudinal muscles.* The longitudinal muscles are inside the circular muscles and are much better developed. They do not form a complete layer but occur as four bundles, two dorso-lateral and two ventro-lateral. Contraction of this muscle makes the body short and stout.

(c) *Oblique muscles.* Two pairs of oblique muscles are found in each segment. They arise from the ventral body wall on the lateral sides of the never cord extending forwards to attach with the bases of the parapodia. The oblique muscles are divided into two parts, one part is attached to the dorsal part of the base of the parapodia and the other to the ventral part. Bending of parapodia in the vertical and horizontal planes is brought about by differential contraction of the various oblique muscle-bundles.

All the muscles are composed of smooth or unstriped muscles fibres.

4. **Coelomic epithelium.** It is the inner most layer of body wall and is composed of single layer of thin cells.

Functions of body wall. The body wall performs a number of functions which are as follows.

(i) The cuticle protects the body from mechanical injuries and desiccation.

(ii) The epidermal glamd cells secrete mucous which lines the burrows to prevent the collapse.

(iii) The epidermis of dorsol side is highly vascular which helps in respiration.

(iv) The sensory cells make the animal sensitive to external stimuli.

(v) Muscles help in movements and serve for locomotion.

(iv) The coelomic epithelium secretes coelomic fluid.

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COELOM

Between the body wall and gut intervenes a fairly specious *coelom* or *perivisceral cavity.* This is not, however, a continuous cavity but, on the contrary, is broken, into a series of coelomic chambers by the intervention of intersegmental septa, corresponding to the external groove. However, the septa, are incomplete, especially round the alimentary canal, so the contiguous coelomic chambers communicate with each other. The coelom is further partitioned by the presence of a pair of oblique muscles running obliquely dorsoventrally from the ventral to the dorsolateral body wall. Ventrally, these muscles are inserted into the body wall below the ventral nerve cord; dorsally they are attached to the body wall near the bases of parapodia. The perivisceral cavity is lined by coelomic epithelium or peritoneum. Peritoneum that lines the inner surface of body wall is called *parietal peritoneum* and that covers the outer surface of viscera is called *visceral peritonium.* A double fold of peritoneum called *mesentery* suspends the alimentary canal into the coelom from mid-dorsal body wall.

The coelom is filled with *coelomic fluid.* This fluid contains amoeboid corpuscles. The coelomic fluid more or less freely

circulate throughout the body.

Fuhctions of coelom. The coelom performs following functions:

1. Food and oxygen are supplied to different parts of the body with the help of coelomic fluid.
2. It protects the body from external shocks.
3. The coelomic fluid also helps in the protrusion of parapodia during locomotion.

LOCOMOTION

Two structural elements are especially important in the locomotion of *Neanthes*, the longitudinal muscles and parapodia. The longitudinal muscles do not from a continuous layer. Instead they are broken up into two pairs of blocks, one pair dorsal and other ventral. Because of this the muscles of the two sides of a segment can be in opposite phases, one contracted and other relaxed so that the passage of waves of contractions along the body can be thrown it into lateral undulations. Assisted by the parapodia the lateral undulations displace the body forward.

The parapodium in *Neanthes* is clearly qulte versatile in its mode of action. The animal remains dependent upon the hydrostatic skeleton to provide firm basis for muscular action. The properties of musculature and parapodia interact to provide for several different types of movements. These movements are of three types:

1. Slow creeping
2. Fast creeping
3. Swimming

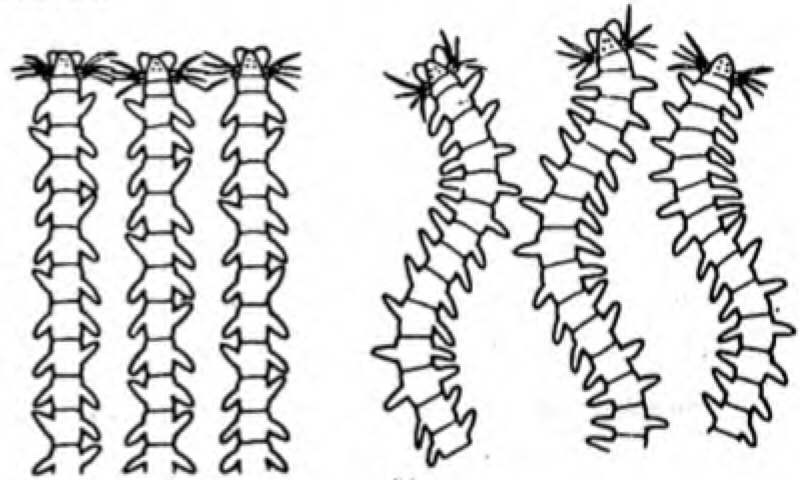


Fig. 41.9 Diagrammatic representation of locomotion in *Neanthes*. A—Slow crawling, B—Rapid crawling.

1. **Slow creeping.** Slow creeping depends almost entirely upon the use of parapodia as a series of levers. Initially a parapodium moves forwards, with its tips lifted from the ground and with the aciculum withdrawn, this is called the *recovery stroke* or *preparatory stroke*. At the end of this stroke the parapodium makes contact with the substratum, the aciculum is protruded, and the oblique muscles contract so that the body is pulled forwards. The parapodium is brought to backwards during this phase which is called *effective stroke* or *power stroke* The movements of parapodia are so integrated that the two members of any one segmental pair alternate with each other in phase. Moreover, the movement of any one parapodium begins slightly after that of the one next behind it.
2. **Fast creeping.** Slow creeping readily passes into rapid creeping. This involves a similar rhythmic pattern of waves, but with the difference that longitudinal muscles are now of primary importance. The contract serially in parallel with the movement of parapodia. The oblique muscles are not probably of much less importance than in show creeping
3. **Swimming.** Here the pattern of movement is essentially the same as that of fast creeping. Sinusoidal waves of the body interact with parapodial movement, but, there is a marked increase in length of the wave and also in their amplitudes and frequency.

DIGESTIVE SYSTEM

It includes alimentary canal and associated digestive glands.

Alimentary Canal. It is a complete straight tube of varying diameters and extends through the entire body from the mouth infront to the anus behind. It can be divided in to three regions:

(i) ***Stomodaeum or forgut.*** It is the anterior region of the alimentary canal, lined internally by ectoderm and cuticle and comprises the buccal cavity and *pharynx.*

(ii) ***Mesenteron or midgut.*** It is middle region of the alimentary canal, and it is lined internally by endoderm and comprising the oesphagus and stomach-intestine.

(iii) ***Proctodaeum or hindgut:*** It is the posterior-most part of the alimentry canal, lined internally by ectoderm and cuticle and comprising only rectum.

(a) *Mouth.* It is a transverse slit on the ventral side of peristomium. It is over by the prostomium. It leads behind into buccal cavity.

(b) *Buccal cavity and pharynx.* The anterior part of the buccopharyngeal regions of *Neanthes* forms an eversible *proboscis.* It is surrounded by several coats of muscles. The buccal cavity is situated in the peristomium and leads behind into the pharynx which extends upto 4th segment. Both of them are lined internally by cuticle. The cuticle of buccal cavity is thickened at various points into dark brown *denticles* or *paragnaths.* The pharynx us thick-walled and muscular. In its posterior part are found of large, powerful, chitinous and movable jaws. Each jaw has a hollow *base* and an incurved, pointed somewhat notched *apex.* The inner margins of the jaws are serrated. The buccal cavity and pharynx are wrapped in a common muscular coat and together they extend up to the fourth or fifth trunk segment. They can be fully everted to form the *proboscis* or the *introvert.* This operation exposes the tips of the jaws for capturing the prey.

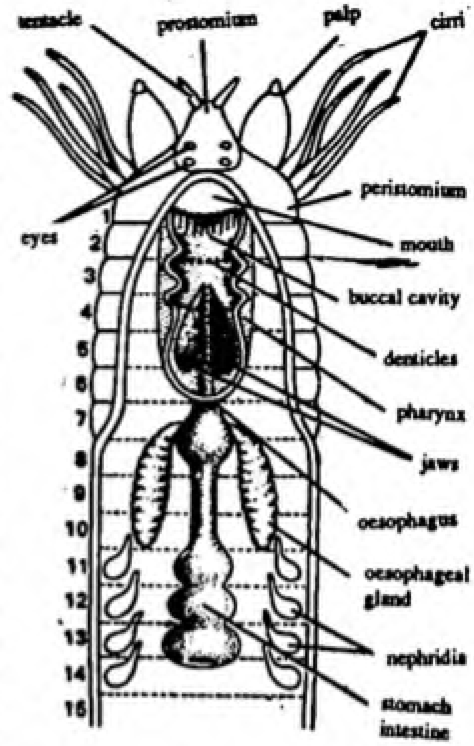


Fig. 41.10 *Neanthes.* Anterior end dissected dorsally to show alimentary canal.

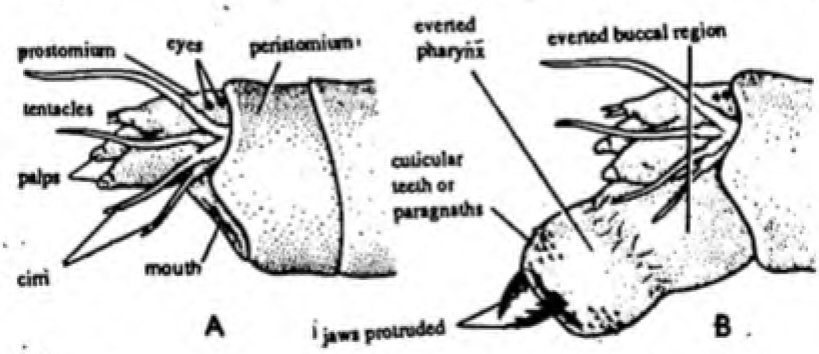


Fig. 41.11 *Neanthes.* A—Pharynx retracted, B—Pharynx everted.

(c) *Oesophagus.* The pharynx narrows posteriorly to lead into the oesophagus. It is a narrow tube extending through five segments behind the pharynx. A pair of long, unbranched, sacculated glandular poches, *the oesophageal gland* or *caeca* open into it laterally at the anterior end. The oesophagus opens into stomach-intestine; the opening between the two is guarded by a sphincter muscle. A distinct stomach is absent.

(d) *Stomach-intestine.* It is a wide tube extending through the remaining length of the body. It is straight, thin-walled tube and segmentally constricted by septa. The stomach-intestine is the principal site of digestion and absorption. The stomach-intestine opens into a rectum which lies in the last segment.

(e) *Rectum.* It is the last part of alimentary canal, which opens posteriorly by the anus. It is very short chamber and occupies the last body segment or pygidium.

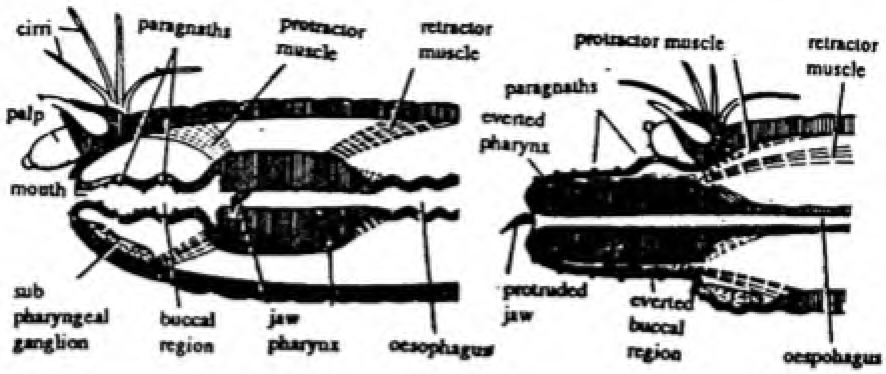


Fig. 41.12 *Neanthes*. Diagrammatic representation of the action of introvest. A—At rest, B—Protruded introvest.

Digestive glands. As stated above into the oesophagus open a pair of laterally placed caecae or poches called *oesophageal glands*. They secrete digestive juices probably proteolytic in nature. Besides microscopic gland cells are present in stomach-intestine. These glands secrete digestive juices that contain enzymes to digest food.

Histology. The gut wall consists of an outer most layer of serosa or visceral peritoreum, followed by longitudinal muscles, circular muscles and an enteric epithelium which is endoderm in the case of mid-gut and ectoderm in the case of fore-gut and hind-gut. The ectoderm is lined by cuticle.

Food. *Neanthes* is a *carnivorous* and *voracious* animal and feeds on small animals, such as molluscs, crustaceans, sponges and other. It is also called clam-worm, because it is generally found, where clams occur. But it never eats the living clams as they are of bigger size. However, it feeds on small animals.

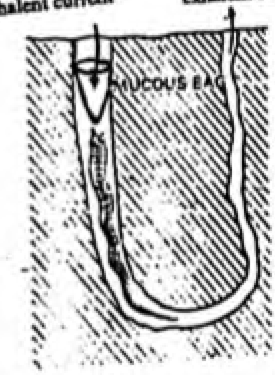


Fig. 41.13 *Neanthes*. File feeding in burrow.

Feeding. To capture the prey, *Neanthes* everts its stomodaecum. The *eversion* of the pharynx is brought about by the contraction of *protractor muscles* extending from the introvert to the wall of peristomium and also by the pressure of coelomic fluid. The muscles contract and the coelomic fluid gets filled in the buccal region, so that the buccal cavity everts out like a bag and the pharynx protrudes out. The two phrayngeal jaws are thrust with their dentate margin facing outwards. The jaws come close together and grasp the prey. The food is now dragged inside the burrow and then swallowed by the withdrawing of pharynx. The retraction of introvert is effected by contraction of retractor muscles which extend from the body wall to the pharynx.

Filler feeding. When within its burrow, *Neanthes* feeds on minute organic particles brought into the tube with the water current.

The water current is created by lateral undulation of the body. For this purpose it secretes a mucous bag. Particles collected in the secretion, as thought in a bag, are swallowed from time to time. This mode of taking food is called filter feeding.

Digestion and absorption. Digestion is intercellular, occurs in the lumen of mid-gut. It is brought by the enzymes secreted by oesophageal glands and gland cells of stomach-intestine. The digestive enzymes are proteases, amylases and lipases. Absorption mainly occurs in the stomach-intestine.

RESPIRATORY SYSTEM

In *Neanthes*, respiratory organs are absent. Respiration occurs by diffusion through body surface. The parapodia with their rich-blood supply and body wall with its plexues of blood vesseles subserve the function of respiration. When the blood passes through these net-works, it obtains oxygen from the surrounding water and gives out carbon dioxide. Blood contains a respiratory pigment *haemoglobin*, which increase the absorptive capacity of blood for oxygen and carbon dioxide.

CIRCULATORY SYSTEM

In *Neanthes* a closed type of circulatory system is present which helps in transportation materials from one region to other region of body. The function of transporting materials is performed by the blood. The blood flows in a system of tubes, the *blood vessels.* The blood vessels are of two types distributing and collecting,. Both the vessels are connected to each other by a system of extremely fine vessels, the *capillaries* . By the peristaltic contraction, the blood is maintained in contant circulation.

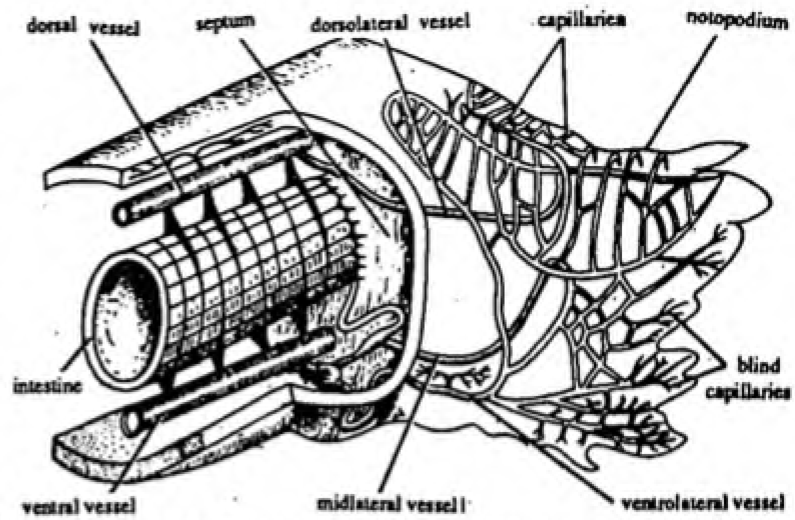


Fig. 41.14 *Neanthes.* Diagrammatic representation of blood vessels in T.S. of a segment.

Blood vessels. There are three longitudinal vessels which are as follows:

(i) *Dorsal vessel.* It runs from one end of the body to the other situated in the dorsal mesentery above the alimentary canal. Its walls are highly contractile which drive blood from posterior to the anterior end. It acts as collecting vessel, but in the 5th segment it bifurcates and both the branches form a plexus to supply the oesophageal wall. Thus dorsal vessel collects blood from the stomach-intestine region by means of two pairs of *dorso-intestinal* or *efferent intestinal vessels* in each segment. It also collects blood from the body wall, parapodia and nephridia through lateral vessels.

(ii) *Ventral vessel.* It is main distributing vessel. It is situated below the gut and in it the blood flows anteriorly backwards. In the last segment it communicates with the dorsal vessel by a simple *circum-rectal ring.*

In each segment, behind the oesophagus the ventral vessel is connected with the dorsal vessel by a pair of loop-like *lateral commissural vessels.* Each of these vessels shortly divides into *afferent* branches, which carry blood to the body wall by *afferent cutaneous,* nephridium by *afferent nephridial* and parapodium by *afferent parapodial* of its side. In these organs, the afferent branches break up into a network of capillaries which reunite to form the corresponding efferent branches. The efferent branches finally unite and open into the dorsal vessel.

In each segment, behind the oesophagus, the ventral vessel also supplies blood to the gut wall through a pair of *afferent intestinal* or *ventro-intestinal vessels* These break up into a capillary network in the gut wall. As stated above from gut the blood is collected by a pair of dorso-intestinal or efferent intestinal vessels and poured into dorsal vessel.

The ventral vessel is a distributing vessel except in the anterior region where it is a collecting vessel and collects blood from oesophageal wall.

(iii) *Peri-neural vessel.* It surrounds the nerve cord. It collects blood from the ventral body wall and sends into the ventral vessel.

Blood. The blood is red in colour due to the presence of dissolved respiratory pigment, the *haemoglobin.* In the blood are present blood corpuscles. The blood corpuscles are colourless, nucleated, amoeboid and resemble the leucocytes of vertebrate blood.

Blood performs a number of functions. It helps in transporting materials, removal of waste products, removing of microorganisms and respiration i.e. exchange of gases.

EXCRETORY SYSTEM

Excretory system consists of metamerically or segmentally arranged pairs of coiled and ciliated tubes, called *segmental organs* or *nephridia.* Each segment, except the peristomium and the pygidium, possesses a pair of nephridia.

Each nephridium is made up of a syncytial mass of protoplasm containing many nuclei. Each nephridium is divisible into

two parts:

1. Body of nephridium
2. Neck of nephridium

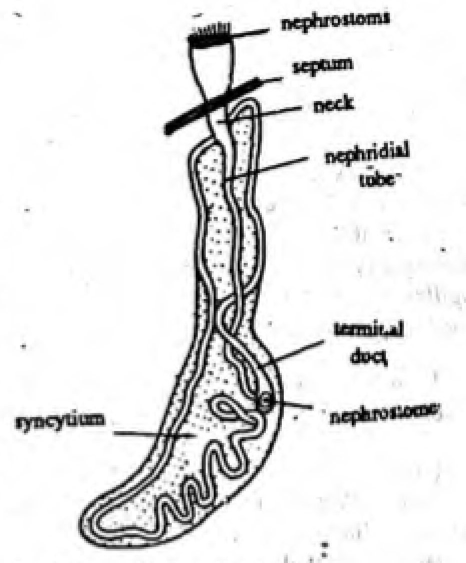


Fig. 41.15 *Neanthes*. A nephridium.

1. **Body of nephridium.** It is a roughly oval, compact gland shaped structure which is placed transversely in each segment and contains a colied ciliated tube in it. The cilia are not found in the its last part called *terminal duct*. The terminal duct opens to the outside by a minute aperture, the *nephridiopore*. The nephridopore is situated on the ventral surface of parapodia near the ventral cirrus. Nephridiopore can be opened or closed.
2. **Neck of nephridium.** The distal part of nephridium is called the neck. In the neck the wall of the ciliated tube is expanded. This part crosses the septum of segment to open into the coelomic cavity of the other where it forms a ciliated funnel-like structure called *nephrostome*. The wide margin of nephrostome is provided with long delicate cilia. Such an open type of nephridium with a ciliated nephrostome is called a *metanephridium*.

In each segment of the body close to the dorsal wall, there is found a pair of *ciliated organs*. These are considered to be the gonoducts of mesodermal orgin, which, however, have lost their external openings and have ceased to function as such.

Excretion is possible by two methods. The outer surface of each nephridium is densely covered with blood capillaries. The cells froming the ciliated tube collect the waste materials from the blood and eleminate it through the nephridiopores. Secondly, ciliated funnel helps in removal of dead coelomic corpuscles, which have been perished by bacteria or some foreign bodies.

NERVOUS SYSTEM

Neanthes is an active animal, therefore, a well developed nervous system is present. It consists of:

(i) Central nervous system
(ii) Peripheral nervous system
(iii) Visceral nervous system

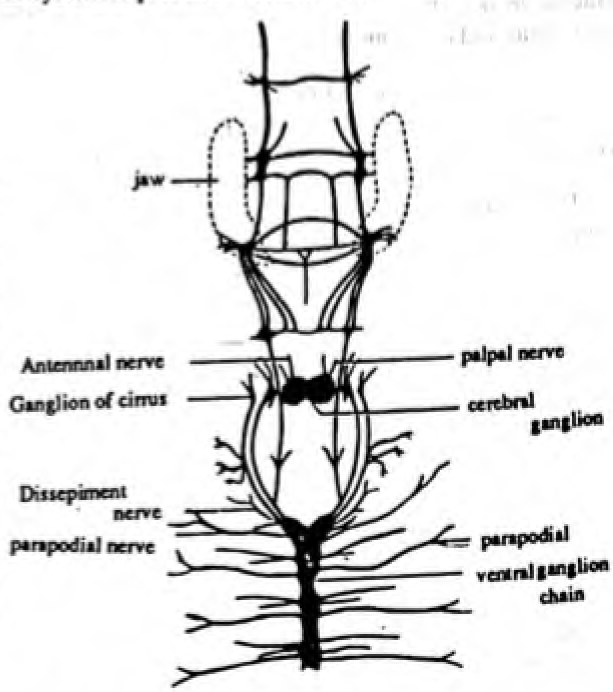


Fig. 41.16 *Neanthes*. Nervous system.

(i) **Central Nervous System.** Central nervous system consists of *brain* or *cerebral* or *supra-pharyngeal* ganglion, which is a large bilobed mass of nervous tissues situated in the protstomium above the pharynx in the head. This is connected to a *subpharyngeal ganglion*, lying ventrally to the pharynx in the 3rd segment by a nerve-collar or *circumoesophageal connective* or *commissure* on either side that forms a *ring* or a *collar* around the pharynx. Following the subphyaryngeal ganglion is the ventral nerve, which is ganglionated and is situated in the midventral line throughout the complete length of the body below the ventral vessels. In *Neanthes*, two ventral nerve-cords are not separate but are fused together along their inner sides and are enclosed in a common connective tissue sheath. The nerve cord is provided with a ganglionic enlargement in each segment. The first ganglion is situated in the 4th segment.

(ii) **Peripheral Nervous System.** The peripheral nervous system mainly includes the nerves coming directly from the brain and

nerve cord to supply the different regions of the body. The brain gives out four short optic nerves to the eyes, two tentacular nerves to the prostomial tentacles, and two palpal nerves to the palps.

The ganglia of the circumpharyngeal connectives supply two pairs of *tentacular nerves* to the two ventro- lateral pairs of peristomial tentacles. The ganglia of the accessory connective innervate the two dorso-letral pairs of prostomial tentacles by a pair of tentacular nerves. From the subpharyngeal ganglion a pair of nerves goes to the first parapodia. Three pairs of nerves arise from each ganglion of the nerve cord, the first goes to the anterior segment and the remaining two pairs innervate the organs of the segment, parapodia and body wall.

(iii) **Visceral Nervous System.** It includes ganglia situated above the pharynx and a few fine nerves. These ganglia and nerves are connected on one side with the brain and on the other side with the ventral surface of the circumpharyngeal connectives.

SENSE ORGANS

In *Neanthes* the sense organs are specialized and well developed. Following types of sense organs are present:

1. **Prostomial palps.** On either side of the prostomium from ventro-lateral surface originate a pair of short, thick and muscular palps. Each palp is made up of two pieces; a basal piece, which is large and a terminal small piece. The terminal piece is capable of retraction into the basal piece. These are tactile in function.

2. **Prostomial tentacles.** These are a pair of small, cylindrical structures arise from the anterior border of the prostomium. The surface of tentacles bear numerous sensory sprial organs, each consisting of about 100 photoreceptive cells, spirally arranged within a cuticular pit. The prostomial tentacles are probably tactile.

3. **Nuchal organs.** These are a pair of small pits in the posterior past of the prostomium on its dorsal side. They are lined with ciliated epithelium and glands cells. They are connected with the posterior part of brain. They serve as organs of smell and chaemo-reception and help the worm in detecting prey.

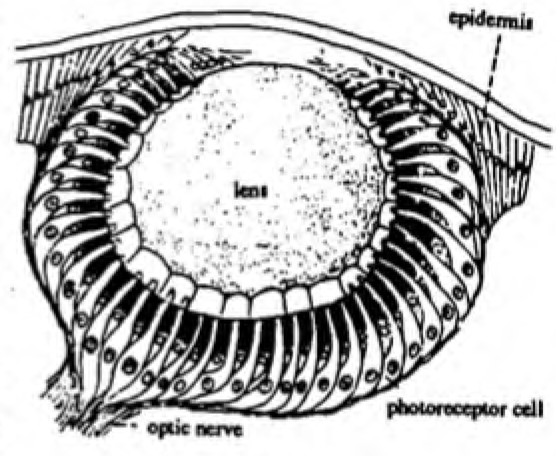


Fig. 41.17 *Neanthes.* V.S. of eye.

4. **Peristomial cirri.** Two pairs of cirri are situated at the anterior end of peristomium. These are regarded to be tactile organs.

5. **Eyes.** There are four simple eyes situated on the surface of the prostomium. Each eye consists of a cup-shaped structure with a pigmented wall made up of radially arranged long, narrow *retinal cells.* Each retinal cell is distinguished into three parts:

(a) An outer nucleated part drawn out into a nerve fibre of the optic nerve.

(b) A highly pigmented middle part or the main body.

(c) An inner part forming a transparent cuticular rod of the hyaline layer.

The cup is filled with a gelatinous matter forming the *lens,* which according to *Andrews,* is secreted by the retinal cells. The outer exposed general surface of the eyes is covered with epidermis, whose cells are more or less flattened, forming *cornea.* The cuticle of the general surface also covers the eye. Retinal cells are continuous with the epidermis at the edges, thus, forming a small opening of the cup towards corena, which functions as a *pupil.* The retinal cells join by means of processes with the brain.

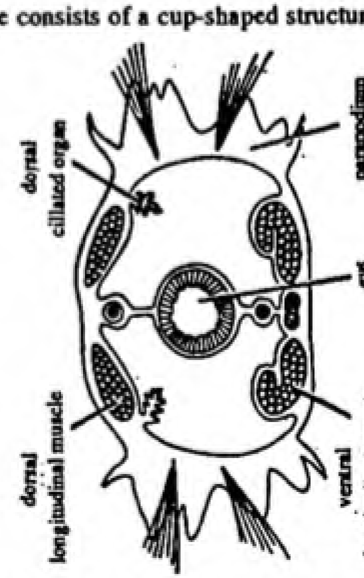


Fig. 41.18 *Neanthes.* T.S. of a segment showing ciliated organs.

REPRODUCTIVE SYSTEM

Neanthes is unisexual and the male and female may exhibit slight sexual dimorphism. The gonads i.e. ovaries and testes are temporary organs, appearing only during breeding season. The breading season is summer, these gonads disappear after the

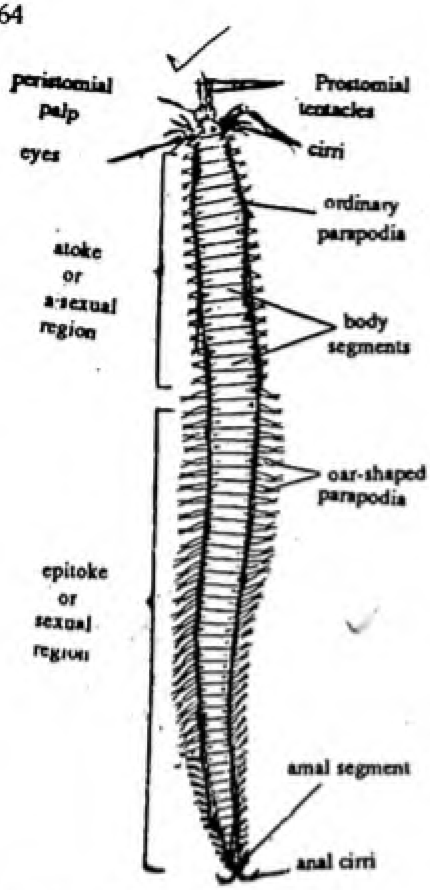


Fig. 41.19 *Heteronereis.*

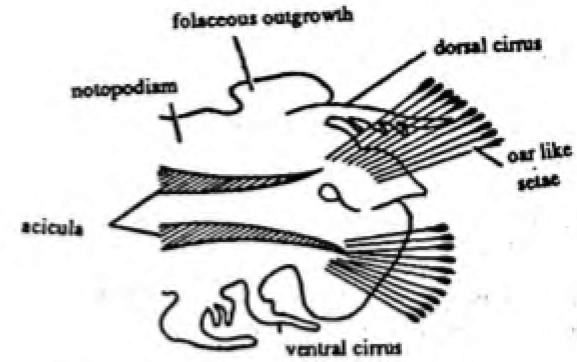


Fig. 41.20 *Parapodium* of Heternereis.

liberation of gametes. In male *N.dumerilli* there is only one pair of testies lying in each segment between the 19th and 25th segments in one of the segments. But in *N.virens* the testes extend in many segments around blood vessels. The gonoducts are absent.

During breeding season the cells which detach from the coelomic epithelium in male constituting the spermetogonium becomes disseminated throughout the coelom. These cells undergo rapid divisions to form spermatids which undergo spermiogeneies to form spermatozoa. A mature spermatozoon consists of a minute rod-shaped *head* and a vibretile *tail.* Similarly the oogonia in female separate into the coelomic fluid and after divisions form the ova which are found floating in it.

The gametes are escaped through the nephridia or by the rupture of body wall. A pair of dorsol *ciliated organs* are found in each segment of the body. Each ciliated organ is a small ciliated tract of folded funnel-shaped structure which opens into coelom by means of a wide aperture. It is believed that they are like coelomoducts and act as gonoducts. During breeding season, they open to the outside by temporary apertures.

HETERONEREIS PHASE

N. dumerilli, undergo remarkable changes in external form and behaviour during breading season. At sexual maturity, most of the posterior segments are filled with gametes. The parapodia are also modified. The notopodia, neuropodia and cirri are enlarged and the formation of additional foliaceous outgrowths occur. The old setae are replaced with much longer, more numerous and oar-shaped setae which are arranged in a fan-like manner. The old parapodial muscles are also replaced by new muscles. This posterior region of body is sexual region or *epitoke* where as the anterior non-sexual region is referred to as *atoke.*

Following characteristics are noted in heteronereies phase:

1. Heteronereis does not crawl on sea bottom but it swims actively on water surface.
2. The eyes become enlarged and the animal properly precieves the light stimulus.
3. The peristomial cirri are comparatively larger than *Neanthes.*
4. The intestine becomes compressed and functionless due to much development of the gonads.
5. Special sensory papillae are formed on the anal segment.

SWARMING

Neanthes swarms on moonless night during summer months after sunset. The males swarms rapidly about the females. Females produce some substance called *fertilium* (not the fertilizin produced by eggs) which attracts males. This fertilizin is

responsible for stimulating and shading of gametes(*Barnes*, 1968). Swarming continues for about an hour or so. Females die after liberation of eggs and probably make also.

Table 2.1

Deferences between *Neanthes* and Heteronereis

Neanthes	*Heteronereis*
1. *Neanthes* is a non-sexual sluggish creature, creeping at the bottom of sea.	1. Heteronereis is an active swimmer on the surface of water.
2. Eyes normal and the worm is less sensitive to light.	2. Eyes become enlarged and conspecuous so that the heteronereis is very sensitive to light.
3. The parapodia are thin, flap-like and non-vascular.	3. The parapodia of the posterior or the sexual part are large, highly vascular and develop leaf-like outgrowths.
4. The setae on the parapodia are normal.	4. The normal setae are replaced by large, flattened and oar-shaped setae.
5. Setae are arranged in the form of bundles.	5. Setae are arranged in fan-like manner.
6. Sensory projections are well developed.	6. Sensory projections become shruken and the anal segment develops special sensory papillae.
7. Dorsol cirri are less curved.	7. Dorsol cirri become altered.
8. The intestine is well formed.	8. The intestine is compressed and becomes functionless due to development of gonads.
9. Less developed for swimming.	9. Better adopted for swimming.

FERTILIZATION

Fertilization is external and takes place in sea water except *Platynereis megalops* where internal fertilization takes place. Here the male inserts its anal segment in the mouth of female. The sperms are passed into the coelom as the intensine is eroded. In the coelomic fluid fertilization takes place.

DEVELOPMENT

The development starts after fertilization of eggs. Each egg is covered in a thick transparent gelatinous envelope. Inside this membrane there are two membranes:

(i) Quter membrane is very thin and delicate.

(ii) Inner membrane is thicker and distinctly striated radially, therefore, it is known as *zone radiata*. The cytoplasm contains numerous yolk spherules and oil drops.

Fertilization produces several changes in the egg. The yolk spherules move at the lower side or vegetal pole, leaving a granular protoplasmic area at the upper or animal pole.

Cleavage. The first two cleavages of the zygote are the equal and vertical and result in four cells or *blastomeres* lying in the same plane. The cleavage is *determinate*, i.e., the fate of the balstomere is fixed and after the four-cell stage, each blastomere gives rise to only one quadrant(quarter) of the embryo. The third cleavage is unequal and horizontal(i.e., at right angles to the first two cleavages) and produces four small *micromeres* towards the animal pole and four large *macromeres* towards the

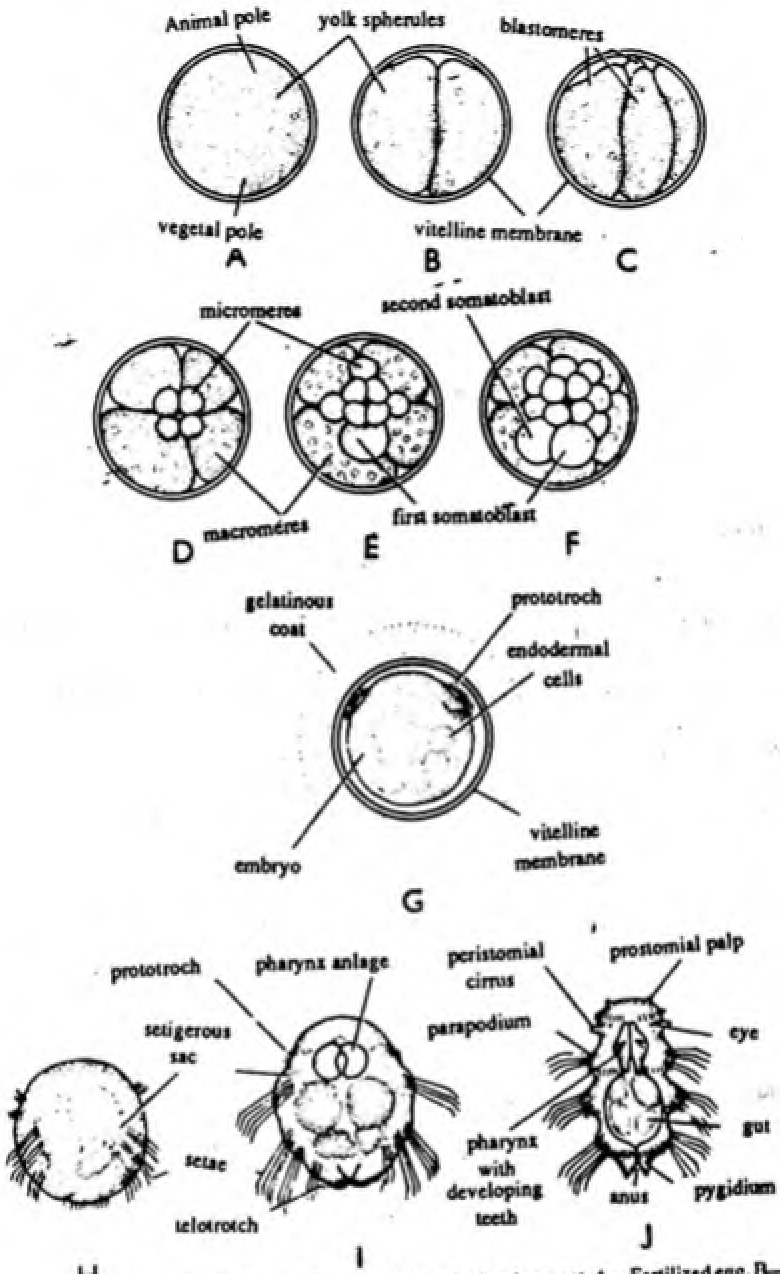


Fig. 41.21 *Neanthes*. Stages in development. A—Fertilized egg, B—Two-cell stage, C—Four-cell stage, D—Eight-cell stage, E—Ist somatoblast formed, F—2nd somatoblast formed, G—Young trochophore before hatching, H—Post trochophore larva with three setigerous segments, I—Older larva, J—Later larva, after three weeks.

vegetal pole. The remaining cleavages are also unequal. The forth, fifth and sixth cleavages are also horizontal and cut off three more quartettes of micromeres from the megameres. The cells of adjacent quartettes lie alternately. This type of cleavage is termed *spiral cleavage*. One micromere of the second quartette and one of the fourth are larger than the others. These are respectively termed the *first* and *second somatoblasts*.

Fore-runners of germinal layers are ready now. The micomeres will gives rise to the ectoderm, the macromeres to the endoderm and the second somatoblasts to the entire mesoderm and a small part of endoderm.

Gastrulation. Micromeres divide and redivide to cover four micromeres and descendants of somatoblast, except at blastopore. On the closing of the blastopore gastrulation is completed.

Development of Trochophore larve. At the top of presumptive end, the first quartent of micromeres differentiates into *apical plate*, which differentiates into *cerebral ganglia* and a tuff of *cilia*. A tuff of cilia develops slightly behind the apical plate and is known as *prototroch*. Stomodaeum (rediment of mouth and oesophagus) develops as an ectodermal invagination and a similar invagination at the position of blastopore forms the *proctodaeum*.

The cells drived by the multiplication of first and second somatoblasts are arranged on the presumptive ventral side of the embryo and form the *ventral plate*. The ectodermal cells present along the ventral side are thickened into *ventral nerve cord*. The deeply situated derivatives of somatoblast give rise to *mesodermal bands* which develop into muscles of body wall and of alimentary canal.

The development starts while the egg floats on water surface.

Trochophore larva. The trochophore is rounded and transparent, it has a thin external ectodermal epithelium which is thickened at the two ends and along an equatorial ring. There is a curved *gut* with a mouth, ectodermal *oesophagus* or stomodaeum, an endodermal *stomach*, and an ectodermal *hind gut* opening by an anus. On the thickened parts of the ectoderm is an anterior ciliated *apical organ* with an apical *ganglion* below which is an *eye spot*, at the posterior end are some large cilia and on the equatorial ring is a large cavity, the *blastocoel* having *mesenchyme cells* larval, *mesoderm* and a pair of larval *nephridia*, each made of two hollow cells, one of which contains a flame of cilia. There lies an otocyst near the nephridia. The trochophore is a small, ciliated larva which is without segmentation and also lacks coelom.

An important point to be noted in the development of *Neanthes* is that the fate of every cell in the early embryo is predetermined. Study of following the fate of cells is called *cell-lineqge*.

In *Neanthes*, the trochophore stage is passed within the egg membrane and the ciliated *nectochaetes larva* comes out of the egg. It possesses three segment and bristles.

Metamorphosis. The nectochaetes larva swims about freely for a few days, feeding on microorganisms and then undergoes metamorphosis to become a young worm. Metamorphosis begins with the elongation of the lower region becomes constricted into segments which soon develop bristles. The ciliated bands disappear and the upper part of the larva becomes the head. The part of larva behind prototroch elongates and develops on its sides two pair of invaginations called *setigerous sacs*. Long setae grow out from the setigerous sacs. A third pair of setigerous sac with projecting setae is also added. The mesenchymal cells multiply and form a pair of mesodermal bands one on either side of the gut. Superficial division of body into segment is accompanied by internal segmentation of mesodermal bands into three pairs of somites. Each somite develops a cavity, the *coelom*. Both the somites of each segment unite above and below the gut forming the dorsal and ventral mesenteries. Later on the ventral mesentray is disappeared . The coelom obliterates the blastocoel. The part anterior to prototroch modified into the prostomium. The part behind prototroch gives rise to the peristomium. The part bearing the anus is continually pushed backwards as new segments are formed in front of it. Tentacles, palps, parapodia with their cirri and permanent setae are formed. Larval setae are dropped. Larval nephridia are replaced by permanent nephridia. The young worm settles down on the bottom and changes into the burrowing adult worm.

SIGNIFICANCE OF TROCHOPHORE

The trochophore larva has much significance since it is found widely in different groups such as as Turbellaria, Mollusca, Bryozoa, Nemertinea, Annelida etc. It has much resemblence with adult rotifers. The early development of the animals of these groups is almost identical and their trochophore stages are also similar in many respects. The differences in their development arise after the trochophore stage. The affinities of annelid trochophore can be discussed as follows:

I. Affinities with adult ctenophore

Similarties

1. Both have oval or pear-shaped body.

2. The apical sensory plate is compared with the aboral sense organ of ctenophore.
3. Subectodermal radiating nerves are comparable in both the cases.

Differences

1. Anus is present in trochophore but absent in ctenophores.
2. Cleavage pattern is different in both.

II. Affinities with Rotifera

The adult rotifer shows following features of similarities:

1. Presence of ciliated bands.
2. Position of anus.
3. Presence of nephridia.
4. Disposition of brain and sense organs.

III. Affinities with Muller's larva of Trubellaira

Muller's larva of *Planocera* shows following similarities:

1. In the position of ciliated bands.
2. Presence of eye-spots at the aboral end.
3. Similarities in the development.

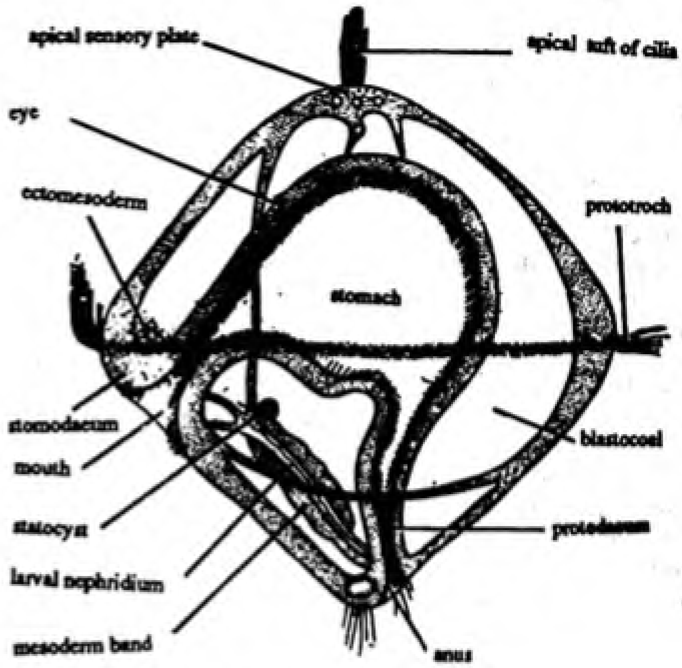


Fig. 41.22 *Neanthes*. A typical trochophore larva.

42

PHERETIMA POSTHUMA

The earthworm belongs to the class Olgochaeta and is represented by about 1000 species. These are cosmopolitan in distribution except Artic and Antartic regions. There are several genera of earthworms including *Lumbricus* of Europe and North America. The common Indian species is *Pheretima posthuma*. It is found in South-East Asia, Japon, Sri Lanka and Australaia. *Drawida* is the chief genus of South India. *Megascolex* found in south, India, Sri Lanka, Australia, North New Zealand and Tasmania. *Eutyphaeus* is restricted to Gangatic plain. The genus *Pheretima* has nearly 500 species of which 13 are exclusively Indian. *Professor K.N. Bhal* brought out an elaborate monograph on *P.posthuma* which broadly applies to most species. The following description is based on the monograph.

SYSTEMATIC POSITION

Phylum	-	Annelida
Class	-	Oligochatea
Order	-	Opisthoproa
Genus	-	*Pheretima*
Species	-	*posthuma*

HABITAT

The earthworms live in the moist soil rich in dead organic metters or humus, in the temperate and tropical regions. They prefer loamy or pasthy sandy soil of old pastures, lawns and garden. They do not prefer very clayey or acidic soils. According to *Henson*, one acre of land may contain 50,000 earthworms, on an average. The earth worms prefer moist soil as their habitat for various purposes. Respiration takes place through the skin, which the wet soil keeps moist for the diffusion of gases. In the soil they obtain their food materials. The moisture and humus make the earth soft for burrowing.

HABITS

1. **Burrowing.** They lives in burrows for the protection against enemies and unfavourable conditions. It makes its burrow by simply pushing the body through the soil, if it is soft, or by eating the soil, if it is hard.' The burrow runs almost vertically into the earth and may be upto 45 cm. deep and its walls are plastered by the secretion of skin-glands. The deeper end of the burrow is rounded and specious so that the worm can take a turn. In cold weather the opening of burrow is closed by dried leaves or characteristic casting of the worm. During dry season the worm descends much deeper (180-210cm). insearch of moisture. During rainy season, when the burrow gets flooded with water, it comes out on the surface.

2. **Nocturnal animal.** It is a *noturnal* in habit, lives in the burrow during the day but comes out in the night for food, which consists of decayed leaves, organic and other animal matters.

3. **Feeding.** Earthworm feeds on dead organic matter present in soil. It takes its food along with the soil by sucking action of its pharynx. Some of the matter is digested in alimentary canal, the undigested residue is eleminated as small pills or pellets on the surface of ground, forming the *worm casting*. The earthworms also feed directly on dead leaves, green alage and other matters.

4. **Breeding.** Although earthworms are bisexual but there is no self-fertilisation. Copulation takes place between two individuals and involves mutual exchange of sperms. The breeding season lasts from July to October. Copulation occurs

at night or early in the morning before sunrise. Each worm lays its ova and sperms in an egg-case or *cocoons* are laid in moist soil. A single worm develops in one cocoon.

5. **Regeneration.** There is considerable power of regeneration in earthworms by which they produce some segments which are removed or damaged.
6. **Grafting.** It is a process by which a small piece of animal is inserted into another worm or its any other part so as to form organic union. A very small worm can be formed by cutting away from its middle a piece of several centimeters and grafting the two ends together.
7. **Enemies.** There are several natural enemies of earthworms. These are frogs, birds, hedgehogs, centipede etc. Bacteria and *Minocystis* are also harmful to these animals.

EXTERNAL FEATURES

Shape, size and colour. *Pheretima posthuma* has a long narrow body which is bilaterally symmetrical. The anterior end is tapering while the posterior end is more or less blunt. The thickest part of the body is always situated a little behind the anterior. The dorsal surface of the body is easily distinguished by the presence of a dark median line of dorsal blood vessel which runs throughout the length of the body just below the skin, while the ventral surface is distinguished by the presence of genital openings and papillae in the anterior part of the body. Size varies from species to species and individual to individual of same species. A mature earthworm, *Pheretima posthuma* may attain the size upto 150 mm in length and 3 to 5 mm in thickness.

The colour of most species is dark brown, the dorsal surface is bit darker then the ventral.

Segmentation. The body is divided into 100-120 segments called *metameres*. Externally the metameres are marked by circular grooves called *annuli*. Similarly, internally the segments are marked by partitions, called *septa*.

Peristomium. A distinct head is absent in the earthworm. The first segment is called *peristomium* containing mouth. The peristomium is prolonged anteriorly into a small fleshy lobe, the *prostomium*. The prostomium is of *proepibolus* type as it slightly encroaches upon the peristomium, between both i.e. peristomium and prostomium there is a distinct groove. The eyes, tentacles as present in *Neanthes* are absent here.

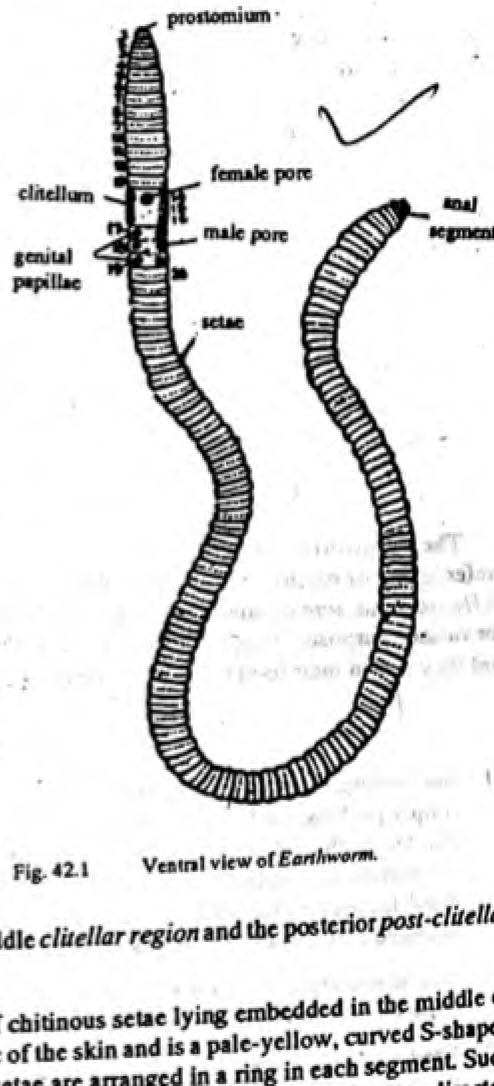


Fig. 42.1 Ventral view of *Earthworm*.

Clitellum. In the adult earthworm the four segments from 14th to the 17th segments are swollen into a ring-like structure called clitellum. The clitellum has many gland cells which secrete the egg case or cocoon. The clitellum divides the body into three regions, namely anterior *pre-clitellar region*, the middle *clitellar region* and the posterior *post-clitellar region*.

Setae. In all segments except the first, last and clitellum there is a ring of chitinous setae lying embedded in the middle of each segments. They project backwards. Each seta arises from a setigerous sac of the skin and is a pale-yellow, curved S-shaped pointed rod-like with a swollon middle part called *nodulus*. In *Pheretima* the setae are arranged in a ring in each segment. Such arrangement is known as perichaetine arrangement. The setae help in locomotion by holding the earth since they are directed backwards. The movements of the setae is controlled by special type of muscles. With the help of these special types of muscles the setae can be moved in any direction and extended or withdrawn at the will of the earthworm.

Anal segment. The last segment of the body bearing the slit-like opening, the anus, is called anal segment.

Apertures. The earthworm has following apertures:

(i) *Mouth.* the crescentic mouth is located at the anterior end of the peristomium. This segment shows longitudinal wrinkles and its dorsal edge projects forwards above the mouth as a fleshy lobe called prostomium.

(ii) Anus. It is slit-like aperture located at the posterior end of the anal segments.

(iii) *Female genital pores.* A single median female genitle pore lying on ventral side of 14 segment.

(iv) *Male genitle apertures.* A pair of male genital pores lie on the 18th segment. In line with the male genital pores, the 17th and 19th segments bear a pair of *genital* or *copulatory papillae.* Each papilla has a shallow pit which looks like an aperture.

(v) *Spermathecal pores.* These are four pairs of spermathecal openings located on the ventral side in the grooves between the segments 5/6, 6/7, 7/8, 8/9. Through these pores spermatozoa are received from other worm during copulation.

(vi) *Nephridiopores.* These are minute pores which are scattered irregularly over all the segments except the first two. Through these pores excretory organs called *nephridia* open out.

(vii) Dorsal pores. These are minute openings lying on the mid-dorsal line in the grooves between the segments. The first dorsal pore is located between the 10th and the 11th segments. The dorsal pores are the openings of the coelom to the exterior.

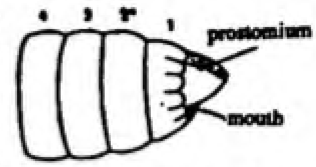


Fig. 42.2 *Pheretima.* Anterior end.

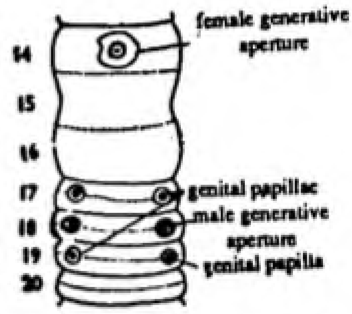


Fig. 42.3 *Pheretima.* Ventral view showing genital area.

BODY WALL

The skin or body-wall is thin, soft, elastic, delicate and moist and consist of following layers from outside.

Cuticle. The cuticle is thin membrane investing the whole body. It is entirely non-cellular in nature and consists of an inner and an outer transparent layer and a thinner and deeply staining middle layer. It bears many perforations through which the epidermal mucous gland cells open out. It is made up of a collagenous protein and polysaccharide along with a little amount of gelatin. The cuticle is secreted by the supporting cells of the underlying epidermis.

Epidermis. The epidermis is a single layer of cells lying beneath the cuticle. It consists of four types of cells, *gland cells, supporting cells, basal cells* and *sensory cells.*

(a) *Gland cells.* The gland cells are of two types:

(i) Mucous cells and (ii) albumen cells.

(i) *Mucous cells,* which are numerous and ovoid. Each mucous cell has a broad distal end and a narrow proximal end, containing cytoplasm and nucleus.

(ii) *Albumen cells.* There are few in a number and each has secretory granules distributed throughout the cell and the nucleus in the proximal end.

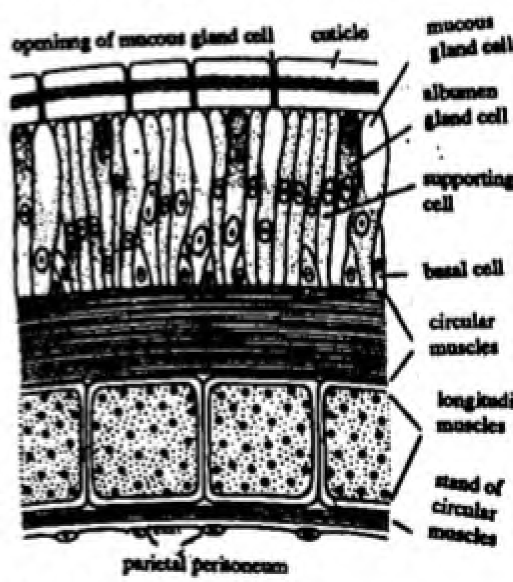


Fig. 42.4 *Pheretima.* V.S. Body wall.

(b) ***Supporting cells.*** The supporting cells are tall and narrow with oval nucleus in the middle of each cells. They form the bulk of epidermis.

(c) ***Basal cells.*** These are small, conical and rounded with a nucleus. These cells are situated between the inner ends of

supporting and gland-cells.

(d) ***Sensory of Receptor cells.*** These cells are found in groups and receive the stimuli, hence are known as receptor cells. In appearance they are like the supporting cells but bear hair-like process at their outer ends.

Musculature. It lies beneath the epidermis and consists of an outer thin layer of *circular muscle fibres* and an inner thick layer of *longitudinal muscle fibres*. The longitudinal muscles fibres are arranged into discrete bundles separated by connective tissue septa. These bundles runs longitudinally. In the zones of setae the bundles of longitudinal muscles are separated by setae.

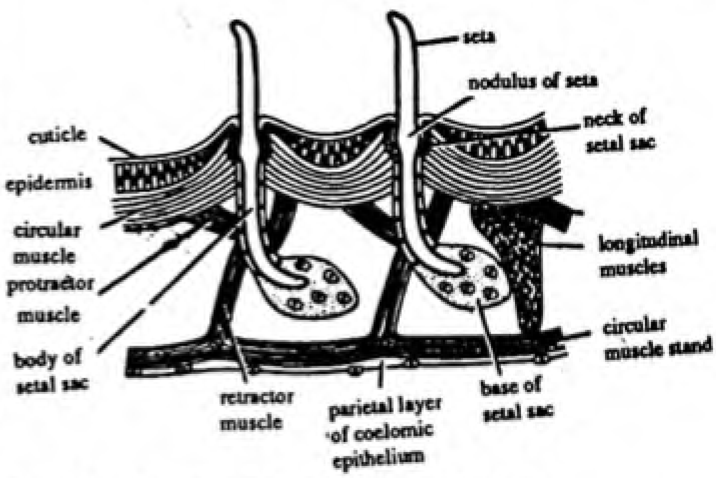


Fig. 42.5 *Pheretima.* A part of body wall showing setae.

The muscle fibres are unstriped, long and spindle-shaped. Pigment cells, connective tissue, nerve fibres and blood capillaries are found among the circular muscle fibres.

Musculature of setal sac. The setal sac arises as an invagination in the epidermis and is distinguished into a base, body and neck. To the basal part of each setal sac are applied two sets of muscles, the *protractors* and *retractors.* The protractor muscles, passing outwards to join the circular muscles, passing inwards to join the circular muscles while the retractor muscle passing inwards to join a thin sheet of circular muscles which lies immediately above the parietal layer of coelomic epithelium. These muscles are responsible for the movement of setae during locomotion. The setae remain and secreted by the large cell of setal sacs.

Functions. The body wall performs several functions which are:

1. It protects the internal more delicate structures from mechanical injury.
2. The cuticle checks excessive evaporation.
3. It is thin, moist and vascular, through which exchange of gases takes place.
4. Mucous secreted by mucous glands of epidermis keeps the body surface clean, free and slimy and cements the walls of the burrow of the worm.
5. Receptor or sensory cells receives the external stimuli.
6. Setae, the organs of locomotion, are lodged in the body wall.
7. The albumen secreted by albumen glands serves as the food for the worms developing inside the ootheca.

Coelom

It is a large perivisceral cavity between the body wall and alimentary canal. It is lined by *parietal epithelium* on the outside and by *visceral epithelium* on the inner side. Each epithelium consists of a single layer of flat or pavement cells. The coelom is not a continuous cavity, but is partitioned into numerous chambers by a succession of transversely placed septa, each of which is inserted into the body wall on one hand and into the wall alimentary canal on the other. Each septum consists of a thin layers of interlacking muscle fibres sandwitched between two layer of coelomic epithelium. Certain striking features about the septa may be noted. There are no septa dividing the coelom of the first four segments, the first spetum of the series being observed between the segments 4 and 5. A few muscular strands, however, pass from the wall of the buccal cavity and the pharynx to the body wall. There is no septum between segment 9 and 10. Septa 5/6, 6/7, 7/8, 8/9 and 10/11 are exceptionally thick, muscular and cone-like and run obliquely backwards from the body wall to gut wall. The first few septa (upto the septum 13/14) are complete and unperforated, but from the septum 14/15 backwards all the septa are perforated by minute apertures. The sphincter muscles regulate the opening of these apertures.

It is thought that the coelomic fluid can be restricted to certain segments by the closure of these apertures, which make those segments turgid and aids to the firmness with which the setae are fixed to the ground during locomotion.

Coelomic fluid. The perivisceral cavity is filled with a colourless or milky alkaline fluid known as *coelomic fluid.* The fluid consists of four types of coelomic corpuscles which are as follows:

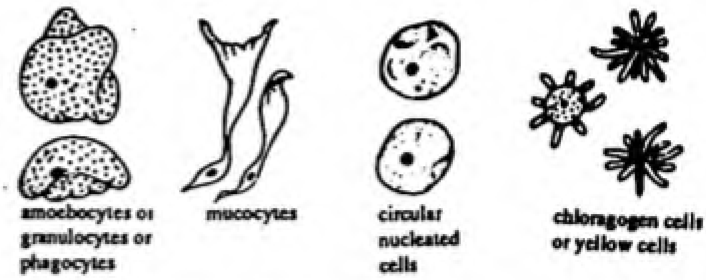


Fig. 42.6 *Pheretima.* Coelomic corpuscles.

(i) *Circular nucleated cells.* These are round and nucleated and possess clear protoplasm. There are also some markings on the general surface and these are about ten percent of the coelomic-corpuscles.

(ii) *Amoeboid corpuscles or phagocytes.* These are numerous and the largest. Each has a deep concavity on one side and is provided with several folds. Each phagocyte has also many ingested granules e.g., bacteria.

(iii) *Chloragogen or yellow cells.* In number, they are as many as phagocytes but are smaller in size. Each cell gives out numerous vesicular projections.

(iv) *Mucocytes.* These are enlongated cells, each consisting of a narrow nucleated body with a broad fan-like structure.

The major part of plasma, in which coelomic corpuscles are found consists of water, some proteins and salts.

Coelom opens to the outside through dorsal pores and ejects coelomic fluid which kills myriads or bacteria of the soil.

Functions. The coelomic fluid performs a number of functions which are:

(i) The coelomic fluid helps in distributions of digested food material.

(ii) It keeps the body moist for respiration.

(iii) It destroys bacteria and harmful parasites.

(iv) It aids in excretion by eleminating yellow cells, which are full of waste products.

(v) The luminosity produced by some earthworms is due to the coelomic fluid.

(vi) It helps in locomotion by causing turgidity.

LOCOMOTION

The earthworm moves by the contractions of the musculature of body wall aided by setae. When an earthworm starts to crawl, the first few segments become thinner but longer. This is due to contraction of circular muscle in that region, elongation being directly caused by an influx of coelomic fluid, which is driven away from the contracting regions into more anteriorly placed segments. The setae of these segments protrude and get a grip of the substratum. The longitudinal muscles of the anterior region now contract, making the region short and thick. As the anterior region is firmly anchored, its shortening pulls the hinder region forwards. These in turn pull the next few segments and so on. These alternating series of waves of extension and contraction aided by the leverage afforded by the setae bring about the locomotion of the worm. Coordination of the waves of muscular contractions is maintained by reflexs passed on from one segment to next by mechanical stimulation and by inpulses passing along the ventral nerve cord. The contraction of both the muscles are also controlled by reflexes.

In order to illustrate the sequence of locomotion in earthworms, *Gray and Lissman* (1938) figured a hypothetical earthworm consisting of only 20 segments. In those segments in which the longitudinal muscles are contracted, the segment as a whole is at its thickest and shortest with setae protruded and contact with the ground. The segment in which the circular muscles are contracted are at their most elongate and thinnest, have their setae withdrawn and are not in contract with the ground.

The body of earthworm moves forward more rapidly. The worm covers a distance of about 25 cm. in one minute. However, it can also move backwards by reversing the direction of the setae. When disturbed, the earthworm performs violent, irregular and jerky movements. The worm can not move over a smooth hard surface like glass plate.

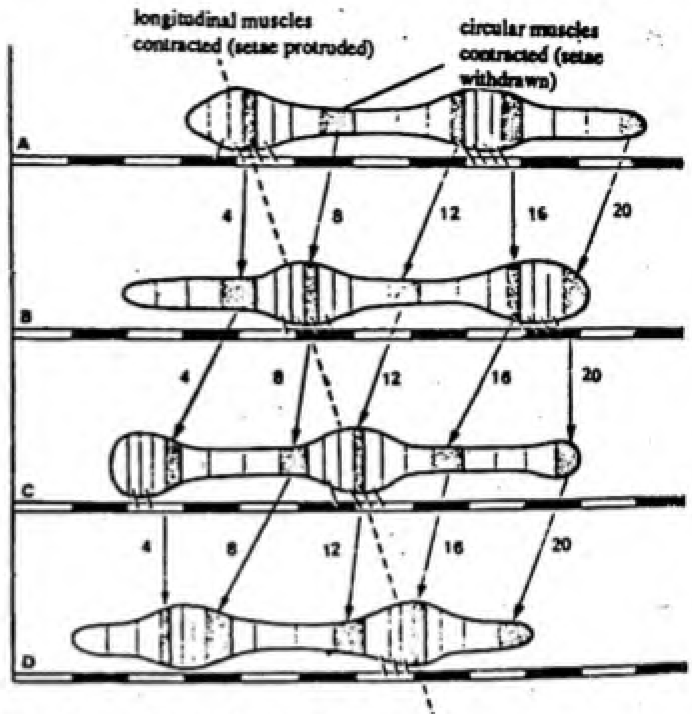


Fig. 42.7 *Pheretima.* Showing locomotion.

DIGESTIVE SYSTEM

The digestive system comprises:

1. Alimentary Canal.
2. Digestive glands.

Alimentary canal. The alimentary canal is complete. It is straight tube of varying diameter. It runs through the entire length of the body from the mouth at the anterior end to the anus at the posterior end. It is held in position by the successive transverse inter-segmental septa. The alimentary canal comprises following parts:

1. ***Mouth.*** The mouth is a crescentic aperture situated on the anterior face of first segment, the peristomium. It is over hung by a small fleshy lobe, the prostomium. It opens into the buccal chember.
2. ***Buccal chamber.*** The buccal chamber extends up to the middle of the 3rd segment. Its walls are slightly folded. The buccal chamber is protrusible and acts as an organ of ingestion of food. The buccal chamber leads into pear-shaped structure, the pharynx.
3. ***Pharynx.*** The buccal chamber leads into a spacious pear-shaped muscular *pharynx*, which extends up to the 4th segments. Its anterior end is marked by a nerve ring placed in a groove between it and the buccal chamber. Its cavity is somewhat dorso-ventrally compressed due to the presence, on its dorsal roof, of a large glandular *pharyngeal mass* producing a salivary secretion. The lateral walls of the pharynx are pushed inside forming a narrow *horizontal shelf* on each side. The two shelves meet anteriorly and posteriorly, thus dividing the pharyngeal cavity into a dorsal or *salivary chamber* and a ventral or *conducting chamber*. The *salivary secretion*, containing *mucus* and proteolytic enzymes, is poured into the salivary chamber.
4. ***Oesophagus.*** Pharynx is followed by a straight narrow, long tube called oesophagus. This thin walled tube extends from the 4th upto 7th segment.
5. ***Gizzard.*** The oesophagus is followed by the gizzard. It is a prominent, oval, hard, thick-walled and highly muscular organ lying in the 8th or 8th and 9th segments. It has thick wall of circular muscles lined by columnar cells. Inside the columnar epithelium is a lining of cuticle. The food is ground up into a fine state inside the gizzard.
6. ***Stomach.*** Gizzard leads into stomach, which extends from 9th to 14th segment. Both the ends of the stomach are provided with sphincters. The walls of the stomach are folded, vascular and glandular. The glandular folds have *calciferous glands* found only in *Eutyphaeus* and *Lumbricus.* These cells produce a calcareous fluid, which neutralises the acidic effect of decomposing leaves, that are taken as foods by the earthworm.
7. ***Intestine.*** the region next to the stomach is the *intestine* which is a long, wide and thin-walled tube extending from the 15th segment to the last. It has a beaded appearance due to constrictions corresponding to septa but bulge in each segment. The internal linings is ciliated, folded, vascular and glandular.

The intestine is divisible into three parts:

(i) *Pre-typhlosolar region.* the first part of the intestine lying between segments 15 to 26 is the pre-typhlosolar region. In

this region the lining of the intestine is folded to form villi which are extremely vascular. In the 26th segment, two short and conical outgrowths, one on either side, are given off from the intestine, these are called the *intestinal caeca.* These extend forwards over three or four segments and have a special blood suply; internally they have many longitudinal folds which appear as villi in transverse sections, epithelial cells being highly vascular and filled with secretory granules, *Chen* and *Puh* (1941) believe that these caeca are digestive glands and secrete an amylatic enzyme which digests starch.

(ii) *Typholosolar region.* This part lies between 26th segments up to 23-25 segments in front of the anus. This is characterized by the presence of a highly glandular and vascular longitudinal ridge, arising as a median ingrowth of the dorsal aspect of the intestinal cavity. This is called the *typholosole.*

(iii) *Post- typholosolar region.* It occupies last 23 or 25 segments. It is without a typholosole and also called as *rectum. It* contains small pallets of mud which are passed out from the anus in the form of castings.

8. *Anus.* It is a slit-like aperture on the posterior face of the anal segment.

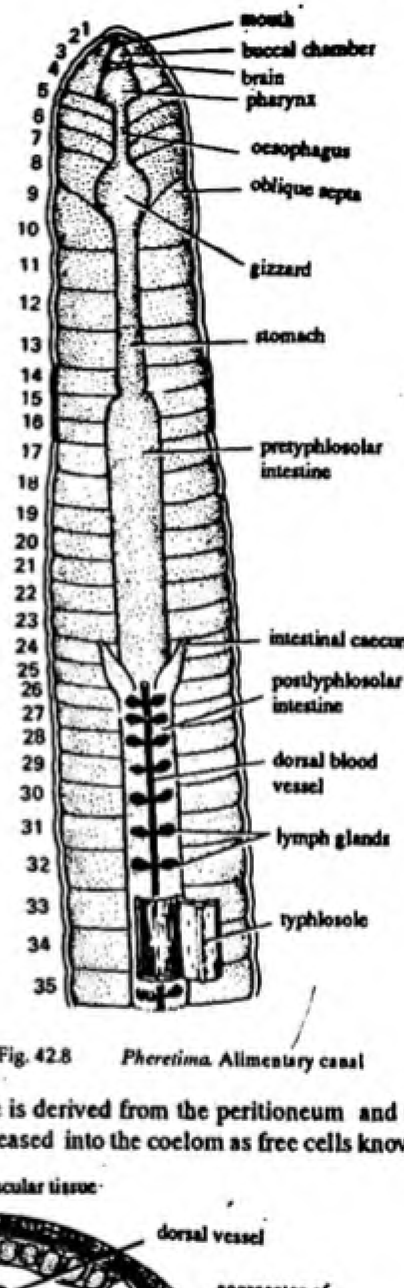


Fig. 42.8 *Pheretima.* Alimentary canal

HISTOLOGY

The wall of alimentary canal consists of four layers in succession. These from outside to inside are:

1. **Perithoneum.** The outermost covering is formed by peritoneal epithelium, which consists of tall and narrow cells. In the stomach and intestine some of these cells are full of yellow refractile granules, hece called, *yellow* or *chloragogen cells.*

Barnes. (1968) mentions that chloragogen cells play a vital role in intermediary metabolism similar to the role of liver in vertebrates. Chloragogen tissue is regarded to be the chief centre of glycogen and fat synthesis. It is also regarded that deamination of protein, formation of ammonia and synthesis of urea also occur in these cells. *Semal Van Gansen* (1956) pointed out that in terrestrial species, the silicates got from food material and soil are removed from the body. Histologically, chloragogen tissue is derived from the peritioneum and its colour is due to the presence of green-yellow lipid inclusions. Chloragogen cells are released into the coelom as free cells known as eleocytes. *Liebman* (1946) describes that eleocytes have food reserves and migrate as different tissues of the body including developing egg. *Semal-Van Gansen* regarded eleocytes as degenerate chloragogen cells, which are destroyed by phagocytic coelomocytes.

2. **Musculature.** It forms the second layer. In consists of an outer layer of *longitudinal muscle fibres* and an inner layer of *circular muscle fibres.* Both these layers are well developed in pharynx and oesophagus but ill-developed in intestine. In the gizzard the main bulk of musculature is represented by circular muscle fibres only. All the muscles are unstriped.

Fig. 42.9 *Pheretima.* T.S. of pharynx.

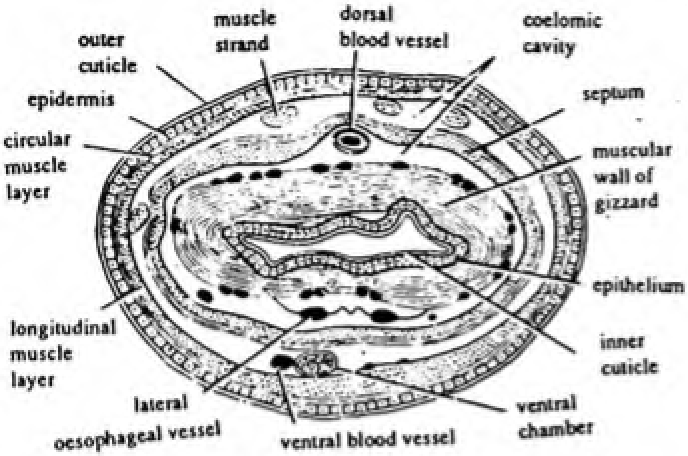


Fig. 42.10 *Pheretima.* T.S. grazzard.

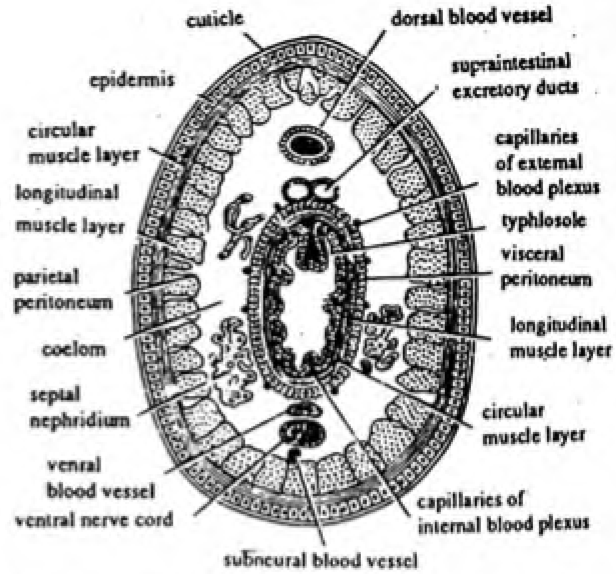


Fig. 42.11 *Pheretima.* T.S. of intestine through typesolar region.

3. **Internal epithelium.** It consists of tall columnar cells covered with thin cuticle in buccal cavity. In pharynx the columnar epithelium is ciliated on the roof and devoid of cilia on the floor. Oesophagus has tall columner cells. In gizzard small cells are covered by thick *internal cuticle.* The epithelium in the intestine has long and narrow *absorptive cells* and *glandular cells* have vacuolated appearance.

II. ***Digestive glands.*** There are three types of digestive glands which are associated with the alimentary canal:

(i) *Pharyngeal mass.* It lies over the pharynx and consists of glandulo-muscular tissue with abundant blood supply. It secretes a proteolytic enzyme and mucous.

(ii) *Gastric gland.* They occur in the entire epithelial lining of stomach which secrete protelyic enzymes.

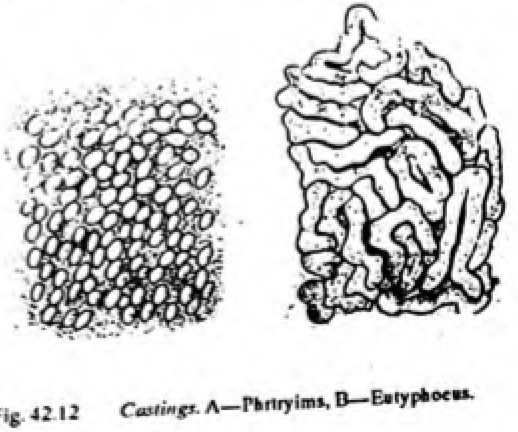
(iii) *Intestinal glands.* They occur in the entire epithelium of intestine. They secrete proteloytic, amylolytic and lipolytic enzymes.

Food and feeding mechanism. The food of earthworms is decaying animal and vegetable matters which are present in soil. They take large amount of soil from the earth that passes through the gut. They also feed directly upon dry leaves, grasses, algae etc. For taking food, they expand the pharynx by the contraction of muscle-bands connecting the pharynx with the body cavity. The enlargement of pharyngeal cavity draws the food into the buccal cavity by sucking action.

Digestion. In earthworms digestion is extracellular. The digestive fluid poured in pharynx contains mucin and some proteolytic enzymes. Mucin lubricates the foods and enzyme starts digestion of proteins. Nothing happen to the food in the oesophagus. The food is ground up in the gizzard.

The soil particles swallowed with the food probably help in the grinding operation. This grinding may be called *mechanical digestion* since it facilitates the subsequent action of the digestive enzymes. In the stomach another proteolytic enzymes are poured which digest more protein. In *Lumbricus* calcium is secreted by calciferous gland which probably neuteralizes the humic acid present in the soil. The final digestion of food takes place in intestine. Here proteins are hydrolyzed into amino acids by proteolytic enzymes like trypsin and pepsin, starch into sugar by the diastase and fats into fatty acid and glycerol by lipase. Intestinal digestive juice of earthworm corresponds with pancreatic juice of higher animals. The passage of food in the alimentary canal is caused by *peristaltic movement* of the gut wall, caused by the

A



B

Fig. 42.12 *Castings.* A—Phrtryims, B—Eutyphoeus.

circular and longitudinal muscles.

Absorption and Assimilation. The digested food is absorbed by the absorptive cells of intestine and is passed into the blood-stream for distribution. The food is ultimately converted into protoplasm of the cells (assimilation). The typhlosole increases the surface area for absorption.

Egestion. The undigested food material is passed out with the large quantities of the earthworm through the anus in the form of casings. The castings of *Pheretima* are in the form of small rounded pallets or balls, while those of *Eutyphaeus* are in the form of heap with an open passage in the middle.

Lymph glands. There are one pair of glands situated on the dorsal surface of the intestine on both the side on dorsl blood-vessel from 26th segment up to the last segment. Each lobule contains phagocyte or amoebocyte. These glands help in breaking up the waste products including cysts and spores of *Monocystis*.

RESPIRATION

Moist skin is the only organ of respiration. It carries on exchange of gases between the environment and the body. Oxygen diffueses across the outermost cells of the skin to the blood. The blood contains a respirator pigment called *haemoglobin*, which greatly increases its capacity for oxygen absorbing. Oxygen combines with haemoglobin to form oxyhaemoglobin. Oxyhaemoglobin gives up oxygen once again to tissues which have a low oxygen tension. In the cells oxygen is utilized in the oxidation of food to liberate energy, besides carbon dioxide is also liberated as waste product. Carbon dioxide is diffused out in the blood. blood with carbon dioxide returns to the skin from where it is diffused out in the surroundings.

CIRCULATORY SYSTEM

Earthworm has a system of vessels or tubes in which red blood circulates which transports, oxygen, carbon dioxide, digested food and nitrogenous waste to and from the parts of the body. A transportation system, in which blood circulates always in tubes, is called a *closed circulatory system*.

The circulatory system comprises: blood vessel, hearts and blood glands.

1. **Blood.** The blood is composed of a fluid plasma and colourless corpuscles which can be comparable to the leucocytes of vertebrates. Haemoglobin occurs dissolved in the plasma which gives red colour to the blood.

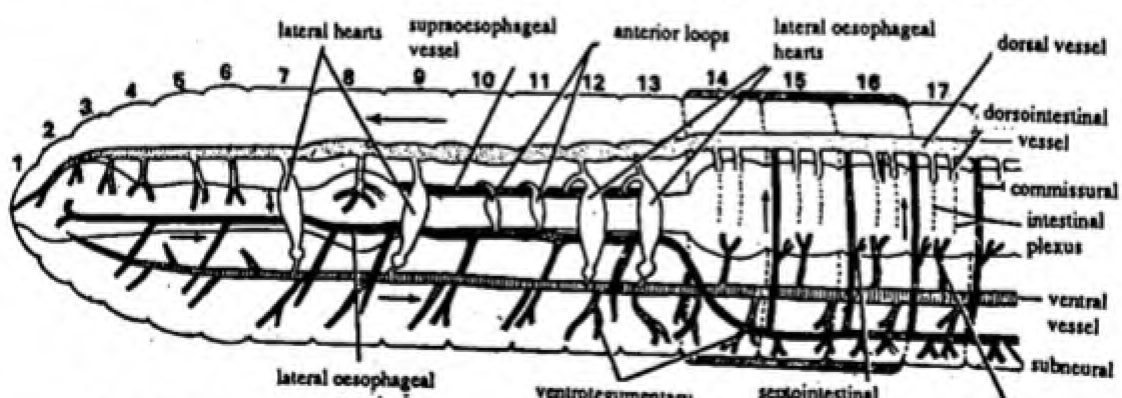


Fig. 42.13 *Pheretima*. A diagrammatic representation of the blood vessels in the first 13 segments (anterior region) of the body.

2. **Blood vessels.** The arrangement of blood vessels is very complicated. The arrangement in the first 13 segment is different from the arrangement of blood vessels in rest of the body. Thus it is easy to describe the circulatory system under two headings:

I. Arrangement of the blood vessels behind the thirteenth segments.

II Arrangement of the blood vessels in the first thirteen segments.

1. ***Arrangement of the blood vessels behind the thirteenth segments.*** In this region there are three main longitudinal vessels namely.

   (i) Dorsal vessel

   (ii) Ventral vessel

   (iii) Subneural vessel.

   (i) *Dorsal vessel.* Dorsal vessel is the largest of the three longitudinal vessels. It runs throughout the length of the body in the mid-dorsal line between the alimentary canal and the body-wall. Its walls are thick and muscular. It shows *rhythmical peristaltic contractions* from behind to the front. The backward flow of blood cannot take place as in this vessel, a pair a forwardly directed valves are found in its lumen in front of each septum. During contraction-movement, the two flaps of valve close down, thus, preventing the backward flow of blood.

In this region dorsal vessel receives blood and thus serves only a collecting vessel but does not distribute the blood. In each segment, it receives two pairs of *dorso-intestinal vessels* collecting blood from two pairs of *transverse vessels* encircling the intestine. It also receives, in each segment, pair of *commissural vessels* one on each side, which are ventrally connected with the *subneural vessel.* Commissural vessels run along the posterior face of the septum, one on either side and receive capillaries from the body-wall and nephridia.

   (ii) *Ventral vessel.* It is a large vessel that runs mid-ventrally below the alimentary canal and above the nerve cord from one end of the body to another. Its walls are thin and non-contractile and the valves are altogether absent. The blood flows through it posteriorly.

The ventral vessel is pricipally a distributing vessel. It supplies blood, in each segment through a pair of *ventro-tegumentary vessels* to the integumentary nephridia, body wall, septa and reproductive organs. Behinds the 13th segment each ventro-tegumentary vessel sends a small branch, a *septo-nephridial branch*, supplying the septal nephridia. Besides these, the ventral vessel, in each segment behind the 13 gives off a median *ventro-intestinal vessel* to the intestine.

   (iii) *Subneural Vessel.* The Subneural vessel runs mid-ventrally below the nerve cord from the 14th segment backwards. It is a thin vessel, the blood flows backwards in the Subneural vessel as in the ventral vessel. It is a collecting vessel and collects blood from the ventral body wall and gives some blood to the intestine.,

II. ***Arrangement of blood-vessels in the first thirteen segments.*** In this region the dorsal and the ventral vessels are continued as such up to the anterior end whereas the Subneural bifurcates into two lateral oesophageal vessel and a new vessel i.e. supraoesophageal vessel is formed on the oesophagus.

   (i) *Dorsal vessel. In* the first 13 segments the dorsal vessel acts as distributing vessel. It sends out all the collected blood from posterior region of the body into ventral vessel through the hearts. By a pair of branches in each segments, 3rd, 4th, 5th, 6th and 8th, to pharyngeal nephridia, oesophagus and gizzard respectively. In extends up to the cerebral ganglion in the middle line of the 3rd segments, where it is divide into three small branches supplying blood to pharyngeal mass and the roof of buccal cavity.

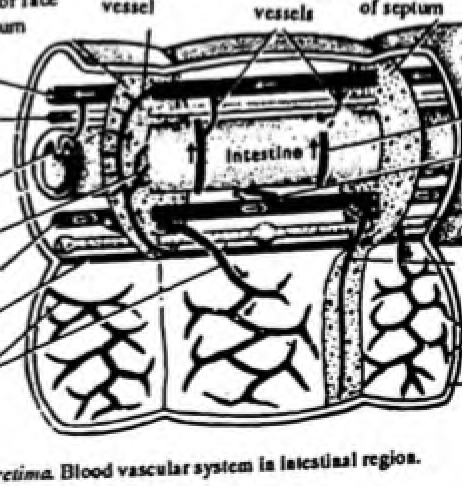


Fig. 42.14 *Pheretima.* Blood vascular system in intestinal region.

   (ii) *Ventral vessel.* It extends anteriorly upto the second segment of the body

and sends blood to the integument, nephridia, septa and reproductive organs through a pair of *ventrotegumentary vessels* in each segment. Ventrointestinal vessels are absent in this region.

(iii) *Supraoesphageal vessel.* It lies on the stomach from the 9th segment to the 13th segments. It is a collecting vessel as it collects blood from gizzard and stomach, it also receives blood form the lateral oesophageal vessels by two pairs of *anterior loops.* The loops are present in 10th and 11th segments. It sends the collected blood to the ventral vessel through *latero-oesophageal hearts.*

(iv) *Lateral oesophageal vessel.* These are two vessels and lie on either ventro-lateral side of the gut running from the anterior end of the body up to the 13th segment. These receive a pair of *ventro-tegumentary vessels* in each segment, collecting blood from the body wall, septa, nephridia and reproductive organs. Flowing posteriorly, some of its blood passes to the *supra*-oesophageal vessel through a pair of anterior loop in each of the segments 10 and 11 and through several ring vessels running through the wall of the stomach. The rest flows backward into the sub-neural vessel.

(v) *Ring vessels.* The stomach possesses in its muscular wall, some circular vessels of typical nature, known as ring-vessels. These are nearly 12 in number in each segment. They convey the blood from lateral oesophageal to the supra-oesophageal.

3. **Heart.** There are four pairs of hearts, one pair each in 7th, 9th, 12th and 13th segments. They pump blood from the dorsal to the ventral vessel. They possess valves to check backward flow of blood. Since the hearts of 7th and 9th segments connect the dorsal and ventral vessels, they are called *lateral hearts.* They possess four valves each. The hearts of 12th and 13th segments communicate both the dorsal and supra-oesophageal vessels with the ventral vessel and are designated as the *lateral oesophageal hearts.* They possess three valves each.

4. **Blood glands.** There are several small red follicular bodies just above the pharyngeal mass in each of the 4th, 5th and 6th segment. These are called glands and are connected to the salivary glands. The follicles have syncytial wall enclosing capsule containing mass of loose cells. These glands manufacture blood corpuscles and haemoglobin and also supposed to be excretory in nature.

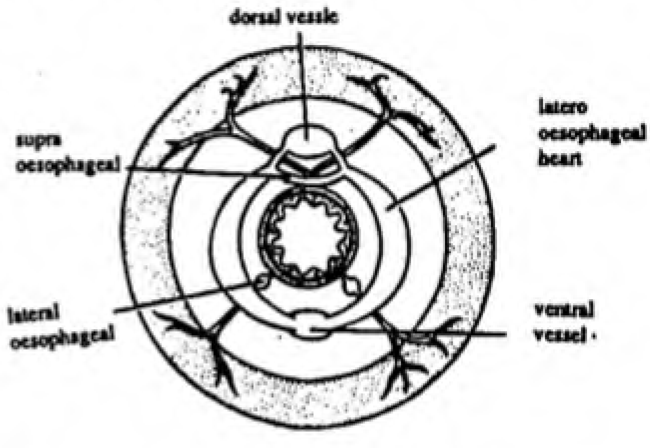


Fig. 42.15 *Pheretima.* T.S. latteral oesophegeal hearts.

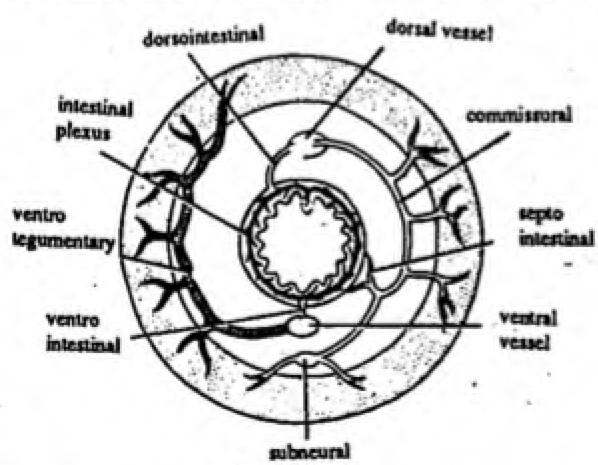


Fig. 42.16 *Pheretima.* T.S. though a segment on the left, and through a septum on the light.

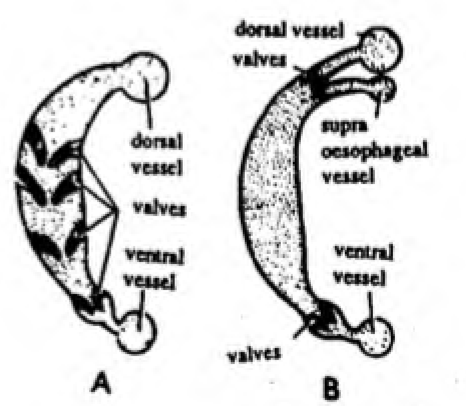


Fig. 42.17 *Pheretima.* Diagrammatic representation of hearts in section. A—Lateral heart, B—Hatero-oesophageal heart.

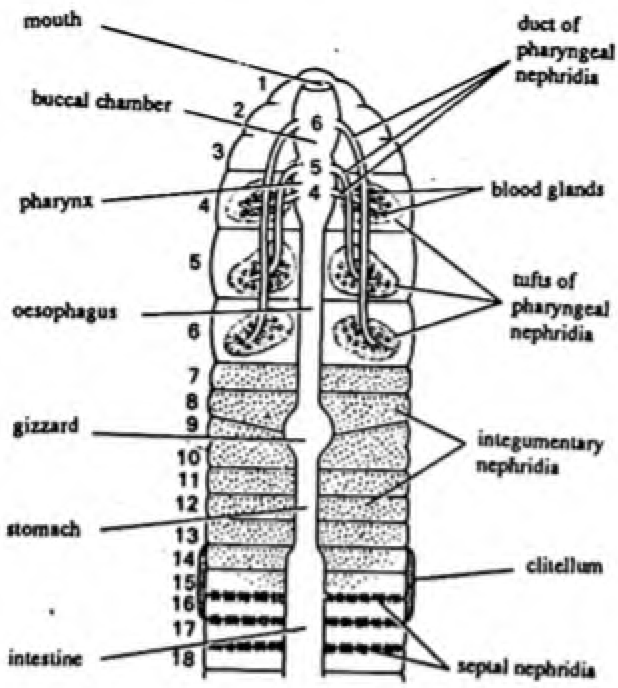


Fig. 42.18 *Pheretima.* Different types of nephridia.

CIRCULATION OF BLOOD

The flow of blood is from behind forwards in the dorsal vessel and from in front backwards in the ventral and subneural vessel. The ventral vessel supplies blood to the body wall septa, nephridia, reproductive organs etc. through the ventro-tegumentary vessels and to the gut through ventro-intestinal vessels. This blood is collected by the lateral oesophageal and subneural vessels. In the first 13 segments blood from gut, body wall, nephridia, septa, gonads etc. is collected by lateral oesophageal vessels and anterior loops. From gizzard and stomach blood is collected by supra-oesophageal which eventually passes its blood to the ventral vessel through lateral oesophageal hearts. In the intestinal region the dorsal vessels collects blood from gut wall through dorso-intestinal and from subneural through the commissural vessels which also receive blood from the body wall, septa, nephridia etc. From the gut wall, the dorso-intestinal vessels carry blood to the dorsal vessel. Thus the dorsal vessel is collecting vessels in the intestinal region where as it is distributing vessel in the first 13 segments supplies blood to the gut and to the ventral vessel through hearts.

EXCRETORY SYSTEM

The organs of nitrogenous excretion consist of segmentally arranged tubules called *nephridia*, which are present in all the segments of body except the first two. In *Pheretima* there is a large number of small-sized nephridia in each segment, such nephridia are called *micronephridia* or *meronephridia.*

Nephridia are of three types according to their position in body:

(i) Septial nephridia

(ii) Integumentary nephridia

(iii) Pharyngeal nephridia.

(i) **Septal nephridia.** Septal nephridia occur on the anterior and posterior faces of all the septa behind the 15 the segment. They are arranged in two rows on each face of the septum, a row on either side of the intestine. They vary from 80-100 per segment. The terminal ducts of all the nephridia in each row open into a *septial excretory canal.* The

two septial excretory canals run upwards along the septum and open into a pair of *supra intestinal excretory ducts* which are situated side by idea in the mid-dorsal line above the intestine and below the dorsal vessel extending from 25th to the last body segment. These longitudinal excretory ducts open the intestine in each segment through narrow *ductules* near the septum. Since the septial nephridia open into the gut, they are described as *enteronephric*.

Each nephridium consists of three main parts:

(a) Nephrostome or Funnel

(b) Main body

(c) Terminal Duct

(a) *Nephrostome or Funnel. The* ciliated funnel or nephrostome is the structure by which each nephridium opens into the coelom. It is a rounded bilabiate structure, having a slit-like opening by which nephridium communicate with the coelom. The funnel consists of a central cell and an upper lip of 8 or 9 cells and a lower lip of 4 or 5 cells. It is followed by a short, narrow and ciliated tube, called the *neck*, which is bent on itself. The *neck* joins the main body of the nephridium.

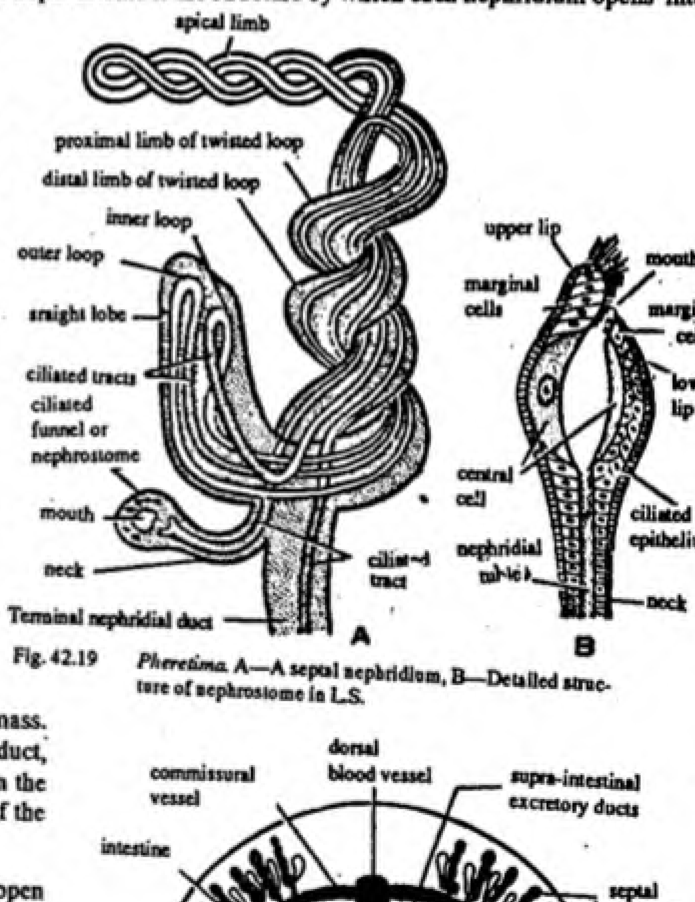


Fig. 42.19 *Pheretima.* A—A septal nephridium, B—Detailed structure of nephrostome in L.S.

(b) *Main body.* It consists of a short straight lobe and a long spirally twisted loop. The *straight lobe* is rounded at its distal free end but is continued at its outer end into the twisted loop, which is more than double the length of the straight lobe. The *twisted loop* can be distinguished into proximal and distal limbs, which are spirally twisted around one another. The distal limb is connected with the straight lobe, while the proximal limb is connected with the neck, ciliated funnel and also given of a terminal nephridial duct. There are four ciliated tracts along the nephridial tubule. The nephridium is made up of a glandular mass. There is a single tube in the neck and terminal duct, while there are four in the straight lobe, three in the basal and two in the apical part of each limb of the twisted loop.

(c) *Terminal duct.* The terminal ducts of nephridia open into a pair of septal excretory canal, which runs inwards along the septa which are described above.

(ii) **Integumentary nephridia.** Integumentary nephridia are small sized, they have no funnel or nephrostome and are of the closed type with no opening into the coelom. Each integumentary nephridium is V-shaped with a short straight lobe and a twisted loop, its lumen has two ciliated canals. These nephridia are attached inside the lining of the body wall from the 7th to the last segment, there are about 200-500 in each clitellar segment. Each nephridium opens by a

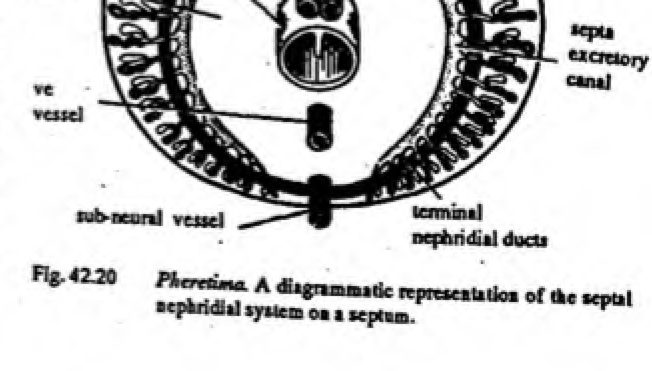


Fig. 42.20 *Pheretima.* A diagrammatic representation of the septal nephridial system on a septum.

nephridiopore on the outer surface of the body wall. Because the integumentary nephridia discharge waste externally they are *exonephric micronephridia.*

(iii) **Pharyngeal nephridia.** The pharyngeal nephridia are similar in size and structure to the septial nephridia as described above, but are lacking in coelomic funnels. These nephridia occur in paired massed, in segment 4th, 5th, and 6th lying besides the pharynx and oesophagus. Their terminal ducts join together to give rise ultimately to one pair of ducts in each of the segments 4th, 5th and 6th. The ducts of the pharyngeal nephridia of the segment 6th open into the buccal cavity in the 2nd segment, whereas the ducts of the nephridia of segments 4th and 5th open into pharynx. The pharyngeal nephridia are interwined with blood glands referred to above.

Physiology of Excretion. Nephridia are chiefly organs of osmoregulation. Nephridia are richly supplied with blood vessels and lined by cilia. The epithelial cells extract waste material, chiefly urea, from the blood. The waste material travel from the body of the nephridium to its terminal duct which discharge it either directly to the exterior or into the alimentary canal.

Working of nephridia covers three functions, filtration, reabsorption and chemical transportation. In open septial nephridia filteration takes place at the funnel, but in other forms of nephridia i.e. integumentary and pharyngeal, filteration takes place through the walls of nephridia. Filteration through nephridial wall from surrounding blood vessel also takes place in septal nephridia where its parts are quite narrow. The filtrate consists of blood plasma minus the colloids together with coelomic plasma. As the filtrate passes through the fine vessels in the nephridia large amount of useful substances are reabsorbed like glucose, amino acids, phosphates, chlorides etc. The process is called selective reabsorption. Finally a protein-free urine containing ammonia, urea and allantoin is put out of the nephridia.

The urine of earthworms is *hypotonic* as contains a far lower concentration of salt than do the blood and coelomic fluid.

Some excretory matter got rid off when the coelomic fluid passes out through the dorsal pores.

NERVOUS SYSTEM

The nervous system is well developed in earthworms and it comprises of:

1. Central Nervous System.
2. Peripheral Nervous System.
3. Sympathetic Nervous System.

1. **Central Nervous System.** It comprises a pair of supra -pharyngeal ganglia, a pair of peripharyngeal connectives, the ventral nerve cord.

A pair of closely united, white, pear-shaped *suprapharyngeal ganglia or brain,* forming the so-called brain, lie dorsally in the third segment in the depression between the buccal cavity and the pharynx. A pair of thick stout *circum-or peripharyngeal connectives* arise from them laterally, embracing the pharynx and meeting ventrally in a pair of fused *subpharyngeal ganglia* lying beneath the pharynx in the fourth segment. In this way, a coplete *nerve ring* is formed around the pharynx.

The ventral nerve cord, arising from the sub-pharyngeal ganglia, runs backwards in the mid-ventral line to the posterior end of the body. In each segment, it presents a slight enlargement or ganglion, the ventral nerve cord appears to be single but it is really double, consisting of two compactly united right and left cords as seen in a transverse section. Each *segmental ganglion* also represents the fusion of pair of gangila, one belonging to each cord of the double ventral nerve cord.

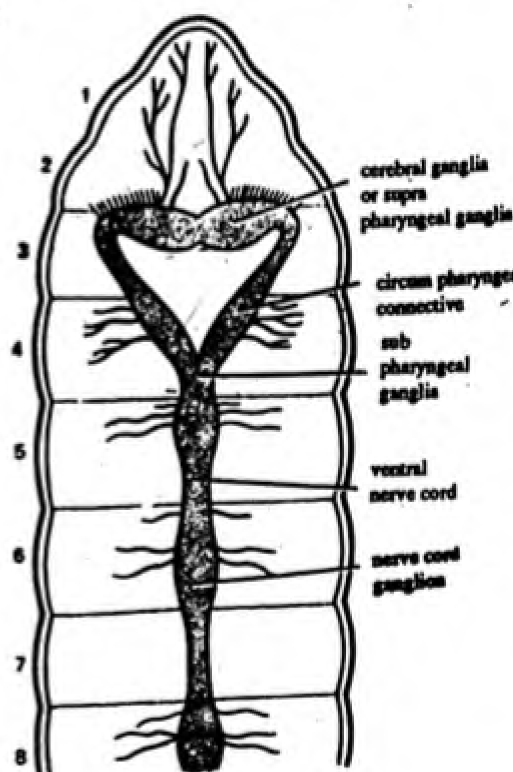


Fig. 42.21 *Pheretima.* Central system.

The entire nervous system contains nerve cells or neurons but these are more numerous in the gangila. As revealed in a transverse section,

the core of the ventral nerve cord consists of two bundles of closely packed nerve fibres. Between these intervene connective tissue fibres are present. The periphery is thin and contains, in the ventral and later zones, neurons, these are also nerve fibres. In the dorsal zone of the periphery there are four gaint fibres, one medium, one submedian and two lateral. These gaint fibres transmit impulses in earthworms.

2. **Peripheral Nervous System.** Various nerves, which are originated from the central nervous system supply different parts of the body, comprise peripheral nervous system. Two nerves arise from each side of the brain and innervate the prostomium and the buccal mass by dividing into number of branches. Peripharyngeal connectives give off nerves into a number of branches. Nerves, arising from subpharyngeal ganglia, intervate 3rd and 4th segments. From each ganglionic swelling of the ventral nerve cord arise three pairs of *segmental nerves* out of which one pair is infront of the row of the setae which intervate the gut wall, body wall and other internal organs of their segment. These nerves are of the mixed type consisting of both sensitive or *afferent fibres* and motor or *efferent fibres.* The afferent fibres connect the sensory impulses. Ganglia change the sensory impulse into motor impulse which passes on to the muscle-cells. The sensory impulses may be transmitted to the muscle of the same segment or may travel along the nerve-cord and thus be transmitted to the muscles of other segments. This arrangement serves for the co-ordination of the activities of the different part of the body.

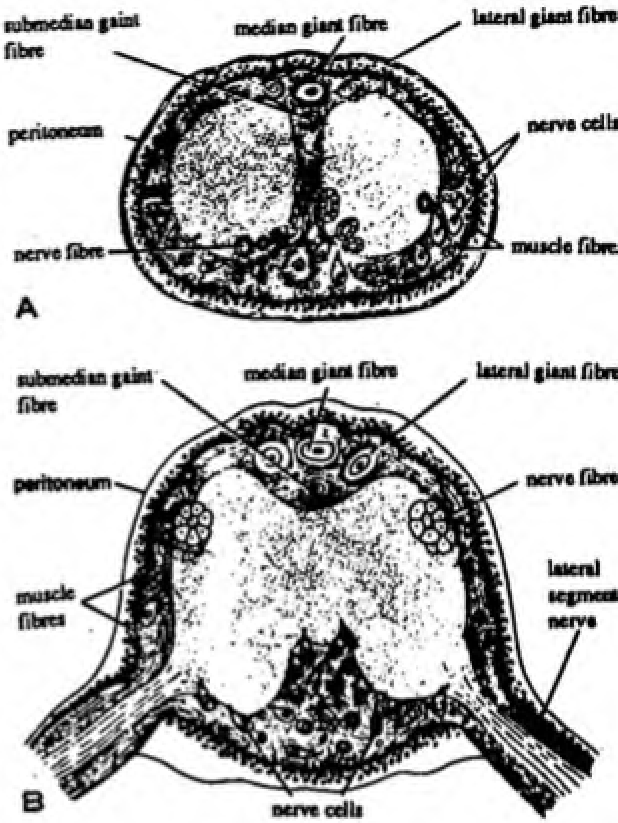


Fig. 42.22 A—Section of ventral nerve cord, B—A section of the ventral nerve cord at the region of the origin of segmental nerves.

3. **Autonomic Nervous System.** It comprises an extensive plexus of nerve fibers present in the lining epithelium and the circular muscles of the alimentary canal. The plexus is connected by fibres with the circumpharyngeal connectives.

SENSE ORGANS

As in other matazoans, the organs concerned with the reception of stimuli from the environment are situated on or near outside of the body. These are called receptor organs or sense organs. These organs are quite simple in structure in the earthworms, consisting of either single or of small group of specialized ectodermal cells. Those lying in groups forming the tectile, olfactory and taste organs, while those occurring single form the light-sensitive organs. Organs of hearing are altogether absent.

There are three types of receptor organs in *Pheretima.*

1. Epidermal receptor
2. Buccal receptors
3. Photo receptors

1. **Epidermal receptors.** These are distributed all over the epidermis but are more abundant on the lateral sides and ventral surface of the body. Each receptor has an elevated cuticle covering a group of tall, slender and columnar *receptor cells,* bearing small hair -like processes at their outer ends and connected with nerve fibres at their inner ends. They are surrounded on all sides by ordinary *supporting epidermal cells.* They are separated from each other by spaces and have nuclei at different levels and posses internally a few *basasl cells.* They are *tactile* (relating to touch) in function and according to some, they also respond to chemical stimuli(*chaemoreceptors*) and changes in temperature (*thermoreceptors*).

2. **Buccal receptors.** These are distributed in the epithelium of buccal cavity in large number. They consist of group of tall cells which project beyond the epithelial cells. They have sensory hair-like procesese and their nucli lie below the middle part. These receptors serve to smell (*olfactoreceptors*) and also taste food (*gustoreceptors*).

3. **Photo-receptors.** These organs are found in large number especially on the prostomium and on-some of the anterior segments. They are not fond in clitellum and on the ventral surface. However, they are few in posterior region. Each organ consists of a single ovoid cell or situated deep in the epidermis. There is a nucleus and clear cytoplasm containing net work of neurofibrilae. There is also a small transparent L-shaped lens or phaeosome which is somewhat tilted. Lens is formed due to a kind of transparent fluid. A few nerve-fibres are also connected with these cells. Lens severs to focus light and nerve-fibrils act as retina.

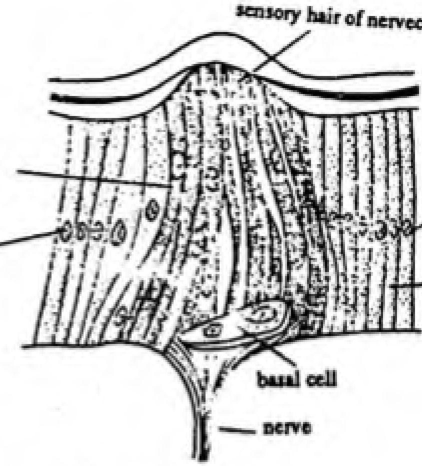


Fig. 42.23 *Pheretima.* A buccal receptor.

Photoreceptors are sensitive to light, but earthworms act negatively to all very weak light, hence they retreat into their burrows during day and emerge at night.

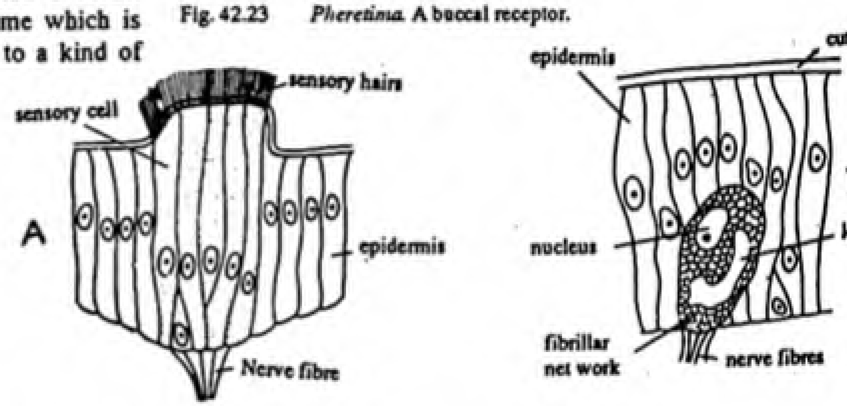


Fig. 42.24 *Pheretima.* A—Buccal receptor, B—Photo receptor.

REPRODUCTIVE SYSTEM

The earthworms are *monoecious* or *hermaphrodite*. The reproductive organs are restricted to a few anterior segments. Though hermaphrodite, the self-fertilization not occurs in earthworm, but two worms pair together (copulate) and later deposit eggs in cocoons. Moreover, the testes ripen earlier(protanday), make cross-fertilization necessary. Thus, hermaphroditism seems to be of no use to the earthworm.

Male Reproductive Organs. The male reproductive system is formed of testes, seminal vesicles, spermiducal funnel, vasa deferentia, prostate glands and accessory glands.

Testes. There are two pairs of testes which produce sperms. These are minute, white and lobed structures. One pair is situated in the 10th segment and the other in the 11th segment on either side of nerve cord. Each testis is made up of a compact narrow base, from which arise 4-8 finger like processes containing spermatogonia.

Each pair of testes is enclosed in a thin-walled, fluid filled bag, the *testis-sacs* situated ventrolaterally, one behind the other, in segments 10th and 11th respectively. The posterior testis sac is larger than the anterior one.

There are two pairs of spermatic funnel or spermiducal funnels in the two pairs of testis sacs. Each funnel is a ciliated structure and lies immediately behind its own testis and opens into a ciliated *sperm duct* or *vas deferens.*

Seminal vesicles. There are two pairs of a large, white seminal vesicles one pair in each 11th and 12th segments respectively. The testis sac of 10th segment communicates with 11th segment and the testis sac of 11th segment with the 12th segment. the seminal vesicles of 11th segment is not visible as they remain enclosed in the testis sac of that segment. However, the seminal vesicles of 12th segment lie free.

Vasa deferentia. Each spermiducal funnel leads posteriorly into a fine ciliated duct, the vas deferens. The vasa deferentia

of the same side travel come together and met a short prostatic duct of that side in the 18th segment.

Prostate glands. There is a pair of large, flat, white irregular organs situated one on either side of the intestine from 16th or 17th upto 20th or 21st segment. Each prostate gland gives off a short duct on its inner side. The prostatic duct is joined by two vasa deferentia, thus, forming three ducts are called common prostatic and spermatic ducts and open to the outside venterally on the 18th segment by the male genital pore. The opening of the male genital pore is actually a group of three apertures, a large prostatic aperture and two small apertures of vasa deferentia. The function of the vasa deferentia is to convey the seminal fluid to the outside for fertilization after copulation.

Accessory glands. The accessory glands are two pairs of rounded masses lying in the 17th and 19th segments just internal to the prostate glands. They open to exterior by a number of ducts on the ginatal papillae situated on the 17th and 19th segments. Their secretion helps probably in uniting the two worms during copulation.

From the testes the spermatogonia are shed into the testis sacs, from where thy pass into the seminal vesicles where they develop into spermatozoa by an elaborate process of spermatogenesis. Each spermatozoon consists of a head and vibratile tail. The sperms come back into the testis sacs and find their way into the spermiducal funnel and travel along the vasa deferentia and finally pass out, through the male genital pores during copulation, into the spermathecae of another worm.

Female Reproductive Organs. The essential organs of the female reproductive system consists of a pair of ovaries, doviducts and 4 pairs of spermathecae.

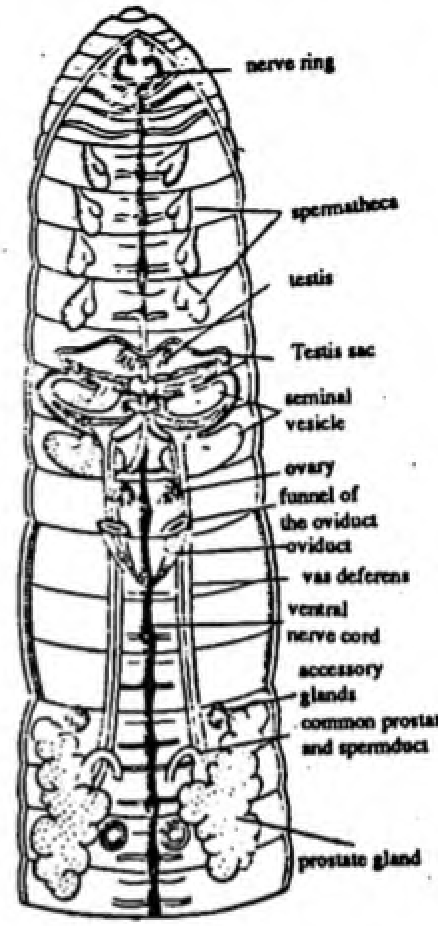


Fig 1.25 *Pheretima. Reproductive System*

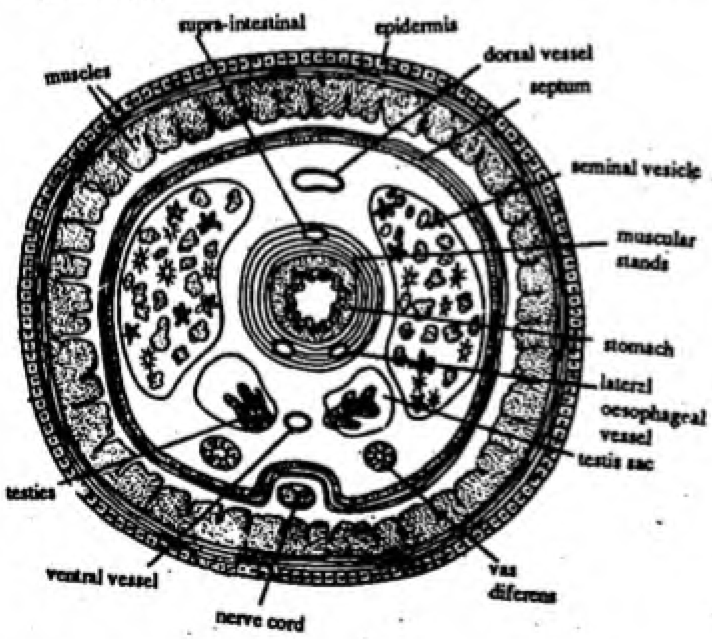


Fig. 42.26 *Pheretima.* T.S. through seminal vesicle.

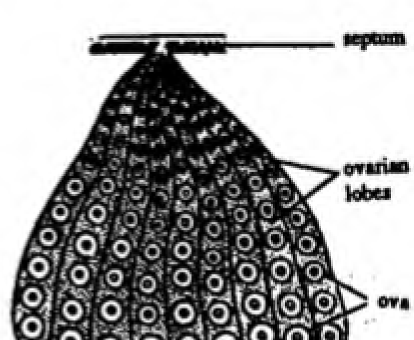


Fig. 42.27 *Pheretima.* Ovary.

Ovaries . The ovaries hang in the 13th segment, being attached to spetum 12/13, one on either side of the nerve cord. Each ovary is a minute whitish mass in which the ova, in various stages of development, arranged in a linear series.

Oviducts. The oviducts are short conical tubes, each with a large oviducal funnel at its free end. Each oviducal funnel is more or less saucer-shaped structure with folded and ciliated margins, and lies immediately behind the ovary. The oviducts run behind, perforate the septum 13/14 and coverage meeting finally in the body wall beneath the nerve cord to form a short common duct that opens the *female genital opening* on the 14th segment. Internally the oviducts the oviduct are ciliated.

Spermathecae. There are four pairs of spermathecae situated in the 6th, 7th, 8th and 9th segments. Each spermatheca is a flask-shaped structure, the body which is known as the *ampulla*. From the narrow neck arises a simple elongated *diverticulum* which stores the spermatozoa in *Pheretima*. In other worms the spermatozoa are stored in ampulla.

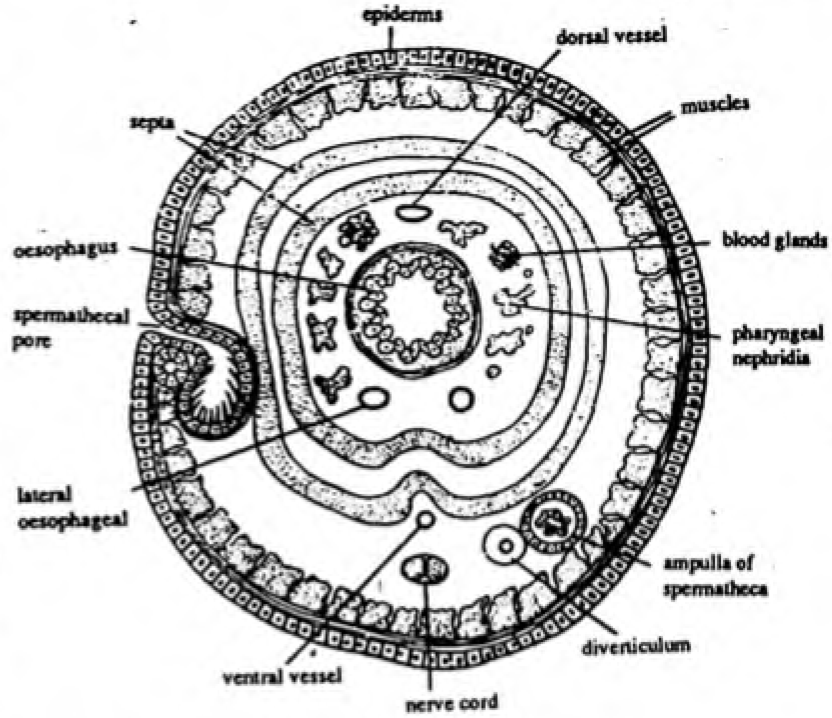


Fig. 42.28 *Pheretima.* T.S. through spermechecal.

COPULATION

During rainy season when the whether is both warm and moist, the earthworms come out of their burrows at night and copulate in pairs. During copulation two earthworms become close applied to each other by their ventral surfaces, with the heads pointing to the opposite directions so that the male genital pores of one is opposite to the spermathecal pores of the other. The areas of male genital apertures are raised into papille which are inserted successively into the various pairs of spermathecal pores from behind forwards thus filing the spermathecae with spermatozoa and prostatic fluid. After the completion of this process both the earthworms are separated and prepare for laying of eggs.

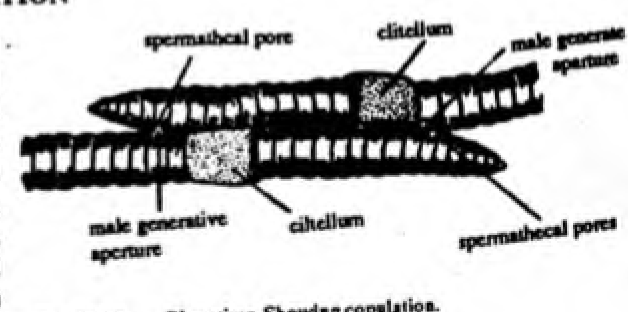


Fig. 42.29 *Pheretima.* Showing copulation.

FERTILIZATION

Cocoon formation is not well known is *Pheretima*, However, it has been studied in other worms like *Eisenia* and *Rhynchelmis etc*. The cocoons are formed usually during the months of August to October. If the condition are favourable the cocoons are also laid in April, May and June.

The cocoon is a product of clitellum. The clitellum is a gridle around the segments 14-16. It has swollen epidermis containing three types of glands in three distinct layers, they are unicelluar mucous glands which secrete mucous for copulation, cocoon-secreting glands secrete the wall of cocoon and the albumen glands produce albumen in which the eggs are deposited in cocoon. The cocoon-secreting glands produce a viscid substance which forms an elastic membraneous tube around the clitellum on coming in contract with air. The earthworm now starts moving backwards so that this tube is pushed forward.

The eggs come out of female genital pore are collected in it. By gradual backward movement of the worm, this tube reach over the spermathecal pores and the sperms are released from spermathecae. Thus fertilization is external. As soon as the earthworm withdraws itself from the tube, the openings due to elasticity closed at both the ends and, becomes a small rounded capsule, called the cocoon. The cocoon thus formed is left in the soil, it is light yellowish in colour and about 2-2.4mm in length and 1.5-2mm in width.

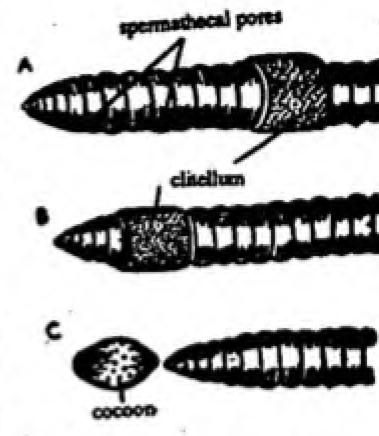


Fig. 42.30 *Pheretima.* Cocoon formation.

DEVELOPMENT

The zygote contains very little amount of yolk. Cleavage is holoblastic but unequal. Two types of cells are formed, the small one are called *micromeres* and the larger ones are called *meagameres.* Continued segmentation results in the formation of a holow spherical body, the *blastula.* The walls of baltula are composed of single-layer of cells, but the cells at the lower end are larger than those above. Two cells lying beside each other near the equator become distinguishable from the rest by the fact that they are quiescent, whereas the rest continue to divided. These are the *mesoblastic pole cells* or pole-cell of mesoderm. After some times these pole cells divide repeatedly to give rise to two rows of small cells, which, together with the pole cells constitute the mesoblastic bands.

Now the blastula elongates and flatens forming a structure with the small cells above and large columnar cells below, while the mesoblast cells lie on the equatorial plane.

Gastrulation beings at this stage by invagination. the lower surface made up of megameres is pushed inwards. The micromeres multiply and keep on growing over the megameres. Due to inpushing a cavity is formed, the *archenteron and the groove,* produced due to invagination is a *blastopore* on lower surface. With the completion of process of gastrulation, the three germs layers are established. The outer embryonic cells constitute the *ecoderm* the cells lining the archenteron, the *endoderm* and the mestoblastic bands, the *mesoderm.*

The blastoporal groove begins to close from behind forwards till only a small opening is left at the anterior end. That persists as mouth and leads into a small *stomodaeum* lined by ciliated ectoderm. The stomodeaum leads into the archenteron. The anus is formed in a very advanced embryo as an ectodermal invagination fusing with the enteron in the last segment of the worm.

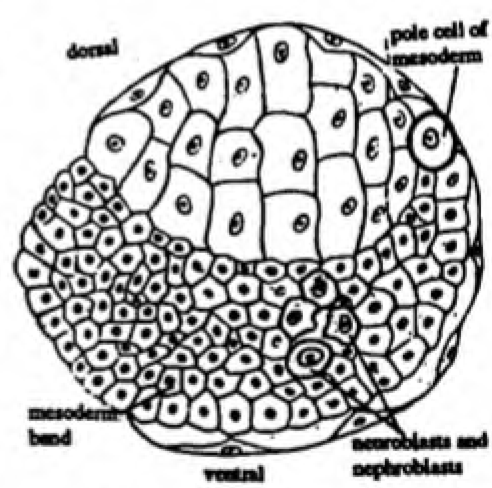


Fig. 42.31 Embryonic development in *earthworm.* Ventro-lateral view of young embryo.

The mesoblastic bands are situated parellal to each other side of mid-ventral line. Each band segments into a row of blocks, the mesoblastic somites, which are solid at first, but develop each, a cavity in the interior secondily. The lateral somites with their cavities grow dorsally and ventrally ultimately fusing with each other, with the result that a continuous space is formed in the mesoderm in contact with the body wall is the *somatoplure* and the inner layer is the *splanchnoplure.* The somatoplure forms the musculature of body wall and coelomic epithelium. The splanchnoplure forms the gut musculature and the coelomic epithelium surrounding it. The partitions between the successive mesoblastic somites persist as transverse septa. In the meantime, the ectoderm cells of the ventral surface of the embryo become thickened and distinguished into four longitudinal rows of cells on each side of mid-ventral line, each row ending posteriorly in a large cells, called and *teloblast.* The two rows of cells immediately on either side on the mid-ventral line, give rise to the *ventral nerve cord,* hence the cells forming it are known as the neuroblast. All kinds of nephridia are produced by nephroblast cells but they differentiate later.

Blood-vessels are formed by the cells of the mesoderm, the ventrl and sub-neural appearing in the mid-ventral line, and the dorsal at the top of the somites of each side. As somites of the two sides meet and fuse above, the paired dorsals fuse to give rise to the median dorsal vessel.

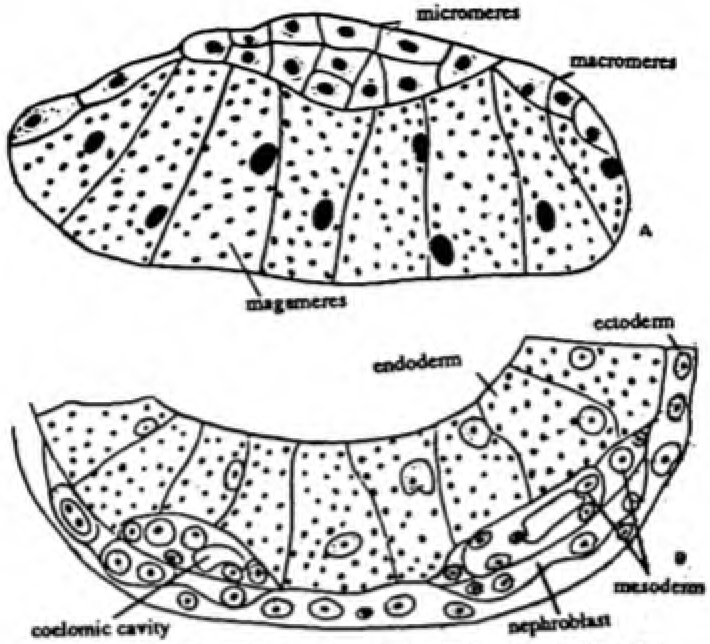


Fig. 42.32 Embryonic development. A—Transverse section of the oval embryo, and B—Ventral portion of a transverse section of an *embryo* showing the mesoblastic somites with coelomic cavities and the demarcation of nephroblast from ectoderm.

Thus the ectoderm gives rise to the epidermis, nervous and excretory system as well as proctodaeum and stomodeaum. Mesoderm gives rise to body musculature, coelomic epithelium and the blood vessels. The endoderm gives rise to the gut and its appendages, glands etc.

Further development of worm takes place by the formation of new mesoblastic somites from behind forwards till the embryonic development is completed.

REGENERATION

Earthworms posses the ability to regenerate lost part, but this ability is limited. A new head may be regenerated after the removal of upto 15 anterior segments, but the capacity to regenerate decreases rapidly behind the 9th segment. The posterior region are more easily regenerated. If the cut is made near the tail end, a new anterior end will not regenerate on the tail half, but instead another tail will develop from cut surface. When any portion of the tail region is cut off, the last parts readily regenerate. The number of segments regenerated is usually less then the number removed.

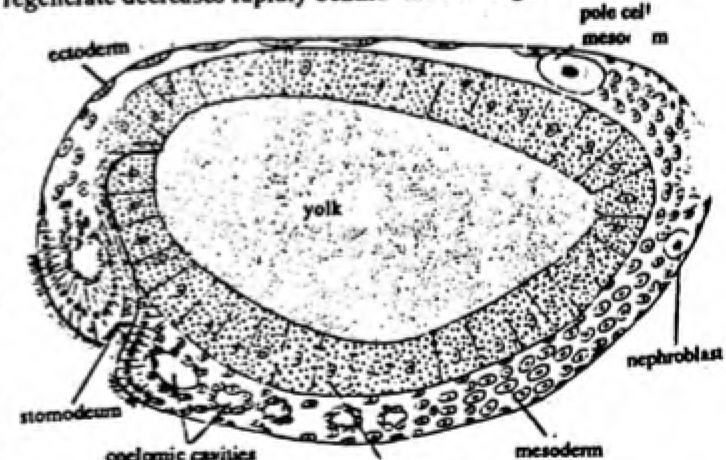


Fig. 42.33 *Embryology*. A longitudinal section of the embryo showing the formation of the stomodaeum and the coelomic spaces.

ECONOMIC IMPORTANCE

The earthworms, apparently tiny and insignificant creature, are of a great economic value to the mankind.

I. The earthworms are beneficial in the following ways.

1. **As baid and food.** All over the world they are used at baid for fishing. They form the best food of fish in aquaria. the earthworms are fed upon by frogs, toads, birds etc., which are useful to man in certain respects.
2. **In agriculture.** Earthworms are in general beneficial

to agriculture. They improve the soil. This is done in many ways. Their habit of burrowing and swallowing earth below the surface increases the fertility of the soil. The soil is made porous which allows better aeration, quick absorption of water and easily penetration of roots. Waste matter and faces thrown out by worms have a good deal of manurial value. The feaces has more nitrate, calcium, phosphorus etc. They bring about optimum conditions for plant growth by reducing both acidity and alkalinity of the soil. A more important beneficial effect on soil is the mixing and churning of solid resulting from burrowing. Deeper soil is brought to the surface as casting and organic material is moved to lower levels.

3. **In medicines.** Earthworms were used variously as medicines in the past to cure stones of bladder, pyorrhoa, jaundice etc.
4. **In laboratories.** The earthworms are studied as a representative of Annelida by students of Biology.

II Harmful activities

Sometimes they destroy tender plands by eating them. Their burrows on the sloping land promote solid erosion during rainy season. They spoil golf grounds.

43

HIRUNDINARIA GRANULOSA

Class Hirudinea (Lat. *Hirudo* = a leech) form a relatively small but well-defined group of segmented worms which are generally adapted to an ectoparasitic mode of life. These are commonly called 'leeches'. About 300 species of leeches are known. They abound in tropical and sub-tropical regions. Most of them are freshwater, while some are marine or terrestrial. Majority are blood suckers and parasitic, others are predators, feeding on worms, snails, insect larvae etc.

Genus *Hirudinaria* includes four Indian species namely, *viridis, H. manilensis, H. javanica* and *H. granulosa. H. granulosa* is the more common species and commonly known as cattle leech.

SYSTEMATIC POSITION

Phylum	-	Annelida
Class	-	Hirudinea
Order	-	Gnathobdella
Genus	-	*Hirudinaria*
Species	-	*Granulosa*

HABITS AND HABITAT

Hirudinaria is a common Indian leech found in India, Burma, Sri Lanka, Bangla Desh and Pakistan. It occurs in freshwater ponds, lakes, slow streams etc., where it either swims by vertical undulations or grips objects with its suckers and moves by looping. It is sanguivorous in diet i.e. feeds on the blood. A single full meal can last for more than a year.

Leech is bisexual but always cross-fertilization occurs. Cross fertilization involves pairing of two individuals in head-to-tail position. Eggs are deposited in cocoons. Development is direct i.e. without any free larval stage in the life history.

EXTERNAL MORPHOLOGY

Shape and size. Body is elongated dorsoventrally flattened and vermiform with flat ventral and convex dorsal surfaces. A fully stretched leech appears to be ribbon-shaped, whereas in contracted condition it is cylindrical. Often it measures about 4-6" but might reach upto 12" or more.

Colouration. The body is beautifully coloured with characteristic markings. The dorsal surface is generally olive-green and the ventral surface is orange-yellow or orange-red and the two sides bear distict stripes of orange or yellow and black. On the dorsal side is a median longitudinal black strip.

Division of Body Body is divided into 33 segments but the external surface of each segment is further divided into annuli by transverse grooves. The number

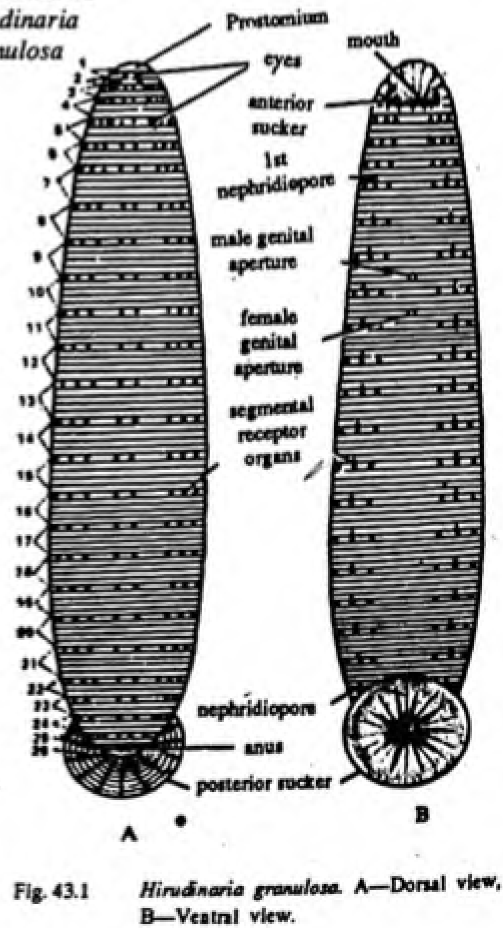


Fig. 43.1 *Hirudinaria granulosa.* A—Dorsal view, B—Ventral view.

of annuli is different in different segments. The entire body can be distinguished into 6 regions.

1. *Cephalic regions.* It is composed of first five (1st-5th) segments and a prostomium, of which 1st and 2nd are uniannulate, 3rd biannulate, and 4th and 5thb are triannulate. Each segment possesses a pair of eyes. On the ventral surface of cephalic region is present anterior sucker and mouth.

2. *Preclitellar region.* It comprises of 6th, 7th and 8th segments. The 6th segment is triannulate and 7th and 8th consists of five annuali. Ventrally, the last annualus of each segment possesses a pair of nephridiopores.

3. *Clitellar region.* It extends from 9th to 11th segments. Each segment consists of five annuli and carries a pair of nephridiopores. Clitellum is distinct only during reproductive season.

4. *Middle region.* It extends from 12th to 22nd segment. All the thirteen segments are quinquannualate (5 annulate) and possess nephridiopores.

5. *Caudal region.* The caudal region comprises of three segments from 23rd to 26th. These are without nephridiopores. Segment 23 is triannulate whereas the rest are biannulate. Anus is located middorsally in 26th segment.

6. *Posterior sucker region.* Posterior sucker is formed by seven segments from 27th to 33rd. These are uniannulate and are arranged in concentric rings.

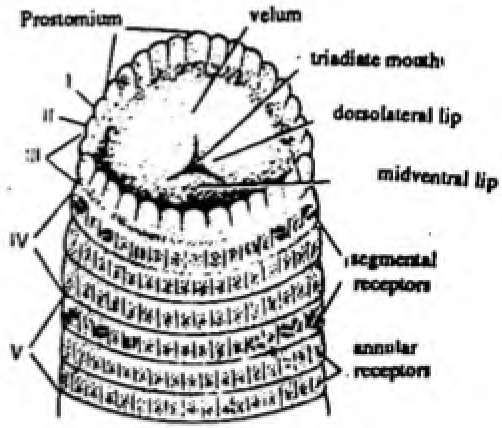


Fig. 43.2 *Hirudinaria.* Cephalic region in ventral view.

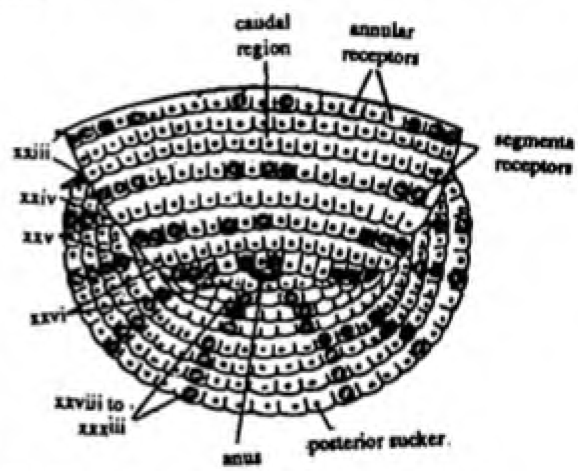


Fig. 43.3 *Hirudinaria.* Caudal region in ventral view.

Suckers. Each end of the body bears a hollow muscular organ, the sucker. The anterior or cephalic sucker comprises the prostomium and three anterior body-somites. It is oval in outline with a ventrally directed, cup-like hollow structure called the pre-oral chamber, at the bottom of which lies the mouth. The posterior end also bears a circular and highly muscular disc, the posterior or anal sucker, also directed downwards. It is formed by the complete fusion of the last seven body segments. Both the suckers are primarily meant for adhesion and locomotion. The anterior sucker also helps in feeding.

Apertures. The body of leech has a number of apertures. These are as follows:

(i) *Mouth.* It is a narrow triradiate aperture situated in the centre of the preoral chamber of anterior sucker.

(ii) *Anus.* It is a small aperture situated mid-dorsally on the 26th segment at the junction of the body and posterior sucker.

(iii) *Nephridiopores.* 17 pairs of minute nephridiopores present on the ventral side of the body, a pair on the last annulus of each of the segments 6-22.

(iv) *Male genital pore.* It is a mid-ventral opening, situated in a groove between the second and third annuli of the 10th somite. Sometimes, a thread like penis is seen protuding through, this aperture.

(v) *Female genital pore.* It lies mid-ventrally in a groove between the second and third annuli of the 11th segment.

BODY WALL

The body wall is made up of five layers viz., cuticle epidermis, dermis, muscular layers and botryoidal tissue.

1. Cuticle. It is the outermost covering of the body and is thin, delicate, transparent, colourless and elastic. It is produced

by the inner epidermis and is periodically shed especially, after a heavy meal. The cuticle is also shed off, if leech is kept in dirty water.

2. **Epidermis.** Lying below the cuticle is the epidermis, which consists of a single layer of hammer-shaped cells. These cells are broad, flatenned and pentagonal towards outer ends and narrower towards their inner ends. The outer ends fit closely while the nucleated inner ends have interspaces containing fibres, connective tissue, pigment cells and haemocloeomic capillaries, forming a vascular and respiratory membrane.

These are several glands found in the epidermis. These are modifications of epidermal cells.

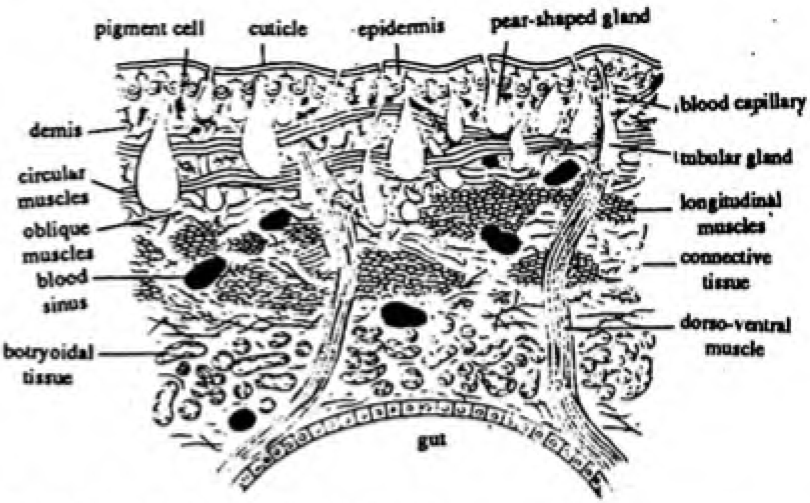


Fig. 43.4 *Hirudinaria.* Section of body wall.

(i) *Slime-glands.* These are distributed all over the body and produce a kind of slimy mucus, which covers whole of the body. The tubular body of the slime-gland reaches deeper into dermis and possesses a nucleus, a thin layer of cytoplasm and several secretory granules. Through the narrow neck, each gland opens to the outside by a minute aperture in the cuticle.

(ii) *Sucker glands.* These are also pear-shaped or rounded in form and occur in clusters in both the suckers. Their secretion serves to smoothen the surface for the attachment of suckers during locomotion.

(iii) *Prostomial glands.* These occur in groups in the prostomium. Their secretion plugs the ends of ootheca or egg- case.

(iv) *Citellar glands.* These are found in the clitellar region (segment 9 to 11) and become active during the breeding season. They are of two special types, the *chitogenous glands* forming the wall of the cocoon, and the *albumen gland* secreting albumen that fills up the cocoon. The former lie between circular and oblique muscles and the latter in longitudinal muscles.

3. **Dermis.** It lies under the epidermis. It also extends into the spaces left between the inner narrow ends of the epidermal cells. It is made of connective tissue and consists of gelatinous matrix containing interlacing fibres and cells. It also contains pigments and fat cells, scattered muscle fibres and branches of haemocoelomic channeles.

4. **Muscles.** The musculature lies beneath the dermis and consists of thin layer of circular muscles and a thicker layer of longitudinal muscles. The longitudinal muscles are powerfully developed and their fibres converge into the two suckers. Circular muscles are arranged concentrically in the suckers. Between the circular and longitidunal muscles leeches have an additional double layer of oblique muscles directed spirally around the body like a coil. There are also dorsoventral muscles arranged segmentally throughout the body, they run from the dorsal to the ventral side in each segment. There are some radial muscles whose fibres radiate from the alimentary canal to the skin, they take the place of septa. The muscle fibres of leech have a characteristic structure, each fibre has an outer striated and contractile cortex or myoplasm, and an inner unmodified protoplasm called medulla or sarcoplasm.

5. **Botryoidal tissue.** It is situated beneath the longitudinal muscles surrounding the alimentary canal. It consists of a network of large branching tubular cells arranged end to end. The walls of the cells are loaded with a dark brown pigment while their lumen or intracellular canals contain haemocoelomic fluid. It is probably excretory in function.

LOCOMOTION

Leeches are capable of crawling as well as swimming.

1. **Crawling movements.** In crawling, the leech first fixes its posterior sucker to the substratum. This is followed by an elongation of the body on the substractum brought about by the contraction of the circular muscles and relaxation of the

longitudinal muscles. The animal then fixes its anterior sucker to the substratum and draws forwards its posterior sucker and the rest of the body by the contraction of the longitudinal muscles and relaxation of the circular muscles. The posterior sucker is then fixed to the substratum close behind the anterior sucker, so that the body forms a loop. The posterior sucker now remains fixed and the rest of the body elongates by the mechanism described above.

2. **Swimming.** It is brought about by the undulatory motion of the body, which is in a state of dorso-ventral flatenning owing to the sustained contraction of dorso-ventral muscles. The undulatory movement is brought about by waves of contraction and relaxation passing along the longitudinal muscles.

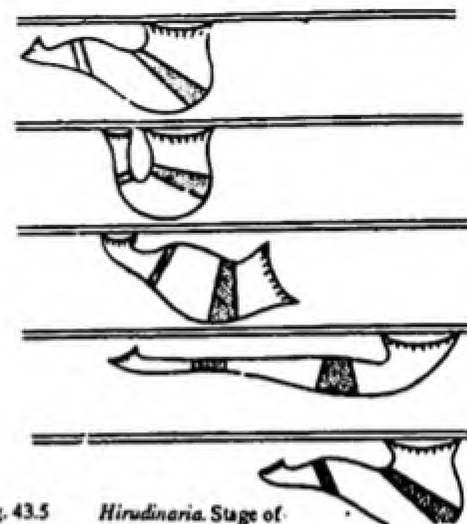


Fig. 43.5 *Hirudinaria.* Stage of locomotion.

DIGESTIVE SYSTEM

The digestive system comprises the alimentary canal and glands associated with it.

Alimentary canal. It is a straight tube of varying diameter running from the anterior to the posterior end. It is supported on all the sides by botryodial tissue. It is differentiated into mouth, buccal cavity, pharynx, oesophagus, crop, stomach, intestine and rectum.

1. *Preoral chamber.* The cup-shaped depression of the anterior sucker represents the preoral chamber. Its base is perforated by triradiate mouth which opens into the buccal cavity. The preoral chamber and buccal cavity are separated from one another by a membranous partition, the *velum*. It consists of three flaps, which form three lips of the mouth.

2. *Buccal cavity.* The mouth leads into the buccal cavity, which is a short chamber behind the velum. In its mucous lining are embedded three cresentic jaws, each lodged in a depression. One jaw lies behind each ray or chink of the mouth, i.e. one is medio-dorsal and the other two ventro-lateral in position. Each jaw is a laterally compressed muscular cushion, covered with fine cuticle which is thickened at the free edge to form a ridge bearing minute teeth or denticles in a single row. Such jaws are termed *monostichodont.* The number of the denticles is 103-128 on the median jaw and 85-115 on lateral jaw. On each side of the jaw are about 42-45 button-shaped protuberances, the salivary papillae, each bearing numerous opening of the salivary glands.

3. *Pharynx.* The buccal cavity is followed by a highly muscular, oval sac, the pharynx. It extends from 5th to 8th segment. It is covered with unicellular salivary glands, whose ducts open into the salivary papillae of jaws. The entire space between the wall and the pharynx is filled up by salivary glands. The saliva secreted by salivary glands has a kind of substance called hirudin or anticoagulin, which does not allow the blood to coagulate during the act of sucking it from the prey.

4. *Oesophagus.* The pharynx opens into the oesophagus, which is a narrow and short section of alimentary canal. The lumen is very narrow and the epithelium is highly folded.

5. *Crop.* The crop is the largest region of the alimentary canal extending from the ninth to the eighteenth segment. It has ten thin-walled chambers, one in each segment. Each chamber consists of a small anterior and a broad posterior part which is produced into a pair of lateral outgrowths the *caeca* or *diverticula.* The chambers and the caeca go on gradually increasing in size towards the posterior side. The last chamber of the crop is the largest and

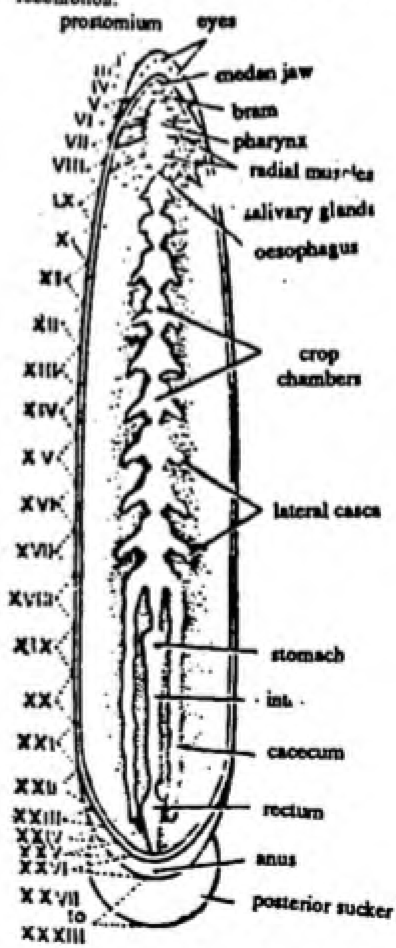


Fig. 43.6 *Hirudinaria.* Alimentary canal.

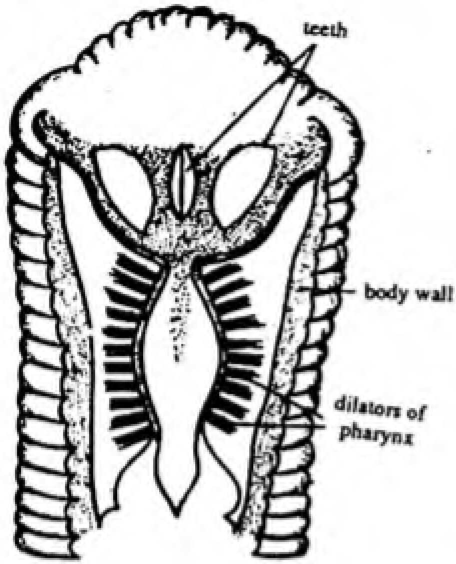


Fig. 43.7 *Hirudinaria.* Ventral dissection of anterior end showing there jaws.

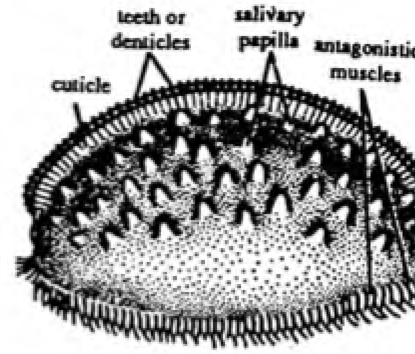


Fig. 43.8 *Hirudinaria.* A jaw.

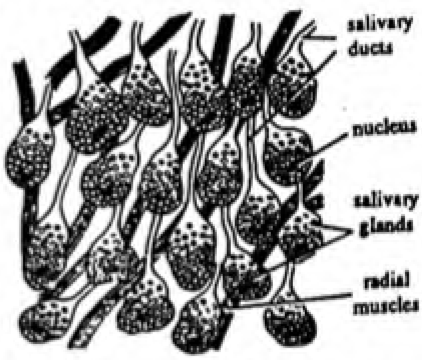


Fig. 43.9 *Hirudinaria.* Salivary glands.

its caeca are prolonged backwards upto the twenty second segment. The crop is a very important part of the alimentary canal, as it is elastic and is used for storing blood, one crop- ful of blood lasts several months.

6. *Stomach.* Posteriorly, the last chamber of the crop ends into a funnel-shaped tube, which leads through a sphinctered aperture into a small heart-shaped stomach, lying in the 19th segment. The mucous lining of the stomach is thrown into anastomosing transverse folds.
7. *Intestine.* It is a thin-walled narrow tube from 20th to 22nd segment. Its lining is also produced into spiral villi-like processes to increase the surface of absorption. The stomach and intestine are not marked externally.
8. *Rectum.* Behind the intestine lies the thin-walled wide rectum which extends upto 23rd-26th segment. There are no internal foldings in rectum. It opens out posteriorly by an anus which lies on the dorsal surface of 26th segment.

Histology

The pre-oral and buccal cavity are lined with cuticle continous with that of external surface. They form the stomodaeum. The rectum is also lined with cuticle and forms the proctodaeum. The remaining parts of alimentary canal are lined with endoderm and forms the midgut.

Food. Food of these highly organised animals is usually blood and, because, they live on the blood of various animals, they are called blood-suckers. Some leeches are parasites on the blood of man, others live on horses and a few on other cattle. Some large leeches in Northern United States, feed voraciously on large snails.

Feeding or ingestion. In feeding the animal attaches itself to its prey by the posterior sucker. At the other end the pre-oral chamber is flatenned and applied to the host. The jaws are protruted through the mouth. Soon the back and forth movements of jaws brought about by special sets of, muscles inserted over them work a triradiate or 'Y'-shaped incision in the skin of victim. The incision lays open the cutaneous vessles from which the blood is sucked with the help of pre-oral chamber, the buccal cavity and the pharynx that form highly efficient apparatus for the purpose. A leech can suck blood several times its own weight in a single meal. When the crops are full of blood it drops of and preers darker places and remains hidden till this meal exhausts. The salivary glands produce a substances, 'hirudin which prevents the coagulation of blood during their feeding time.

Digestion. In the crops the blood is haemolyzed i.e. the red blood corpuscles burst and give up their haemoglobin into the

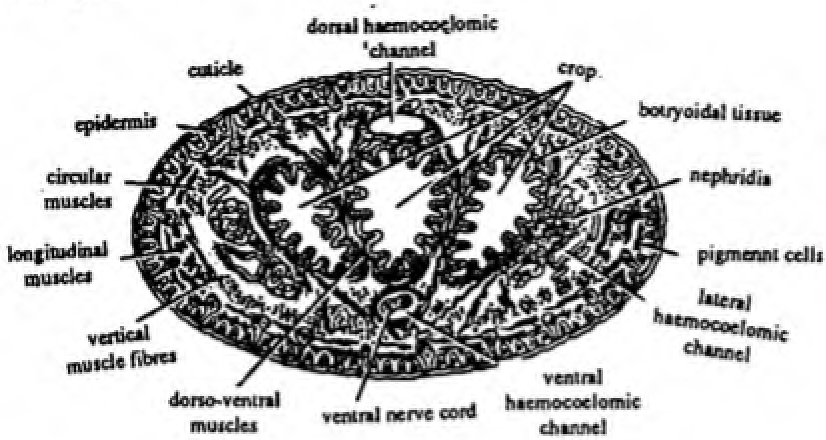


Fig. 43.10 *Hirudinaria.* T.S. body through crop and its diverticula.

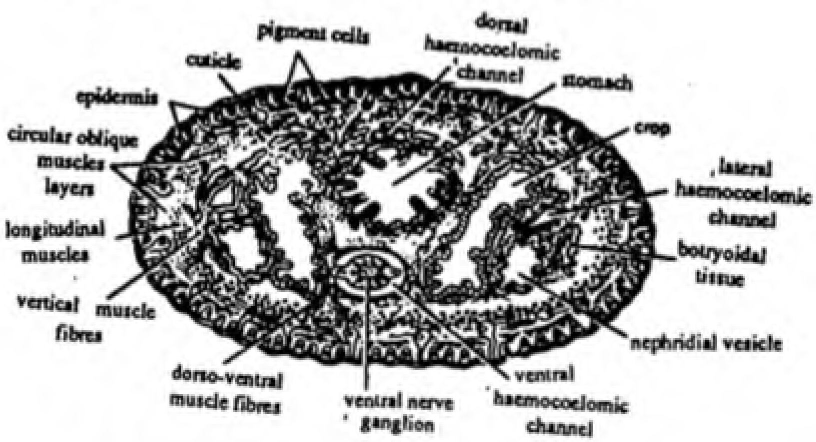


Fig. 43.11 *Hirudinaria.* T.S. body through the region of stomach.

plasma. Some water is absorbed in the thin walls of the crops. Digestion of haemolyzed blood takes place in the stomach by the proteolytic enzymes (*Abderhalden* and *Heise*, (1909). *Busing* and his colleagues discovered in 1953 that digestion in *Hirudo* occur entirely by the gut bacteria. The process of digestion is very slow and it takes 10-14 months to digest one crop-full of blood.

Absortion. Digested food is absorbed in the intestine. The absorptive surface of intestine is increased by villi-like transverse and longitudinal folds.

Egestion. Elemination of indigested food occurs through the anus.

Coelom. Coelom, as seen in *Pheritima*, is not present around the alimentary canal of the leech. Actually, the coelom is present, although in a considerably reduced state, owing to the growth of botryoidal tissue. It is represented by the four longitidunal vessels, which are not true blood vessels, but shut off parts of the coelom, the branches of these vessels and a fairly large number of spaces.

The coelomic fluid, running through the channels and their branches, contains colourless amoeboid corpuscles and is coloured red due to haemoglobin dissolved in it. The blood-like coelomic fluid is called the haemocoelomic fluid and the channels are termed the haemocoelomic channels, which together form the haemocoelomic system.

Thus, in *Hirudinaria*, there are no true blood vessels, their function being taken up by the haemocoelomic system.

Haemocoelomic system. It consists of following four longitudinal vessels:

1. A dorsal longitudinal channel

2. A ventral longitudinal channel

3. Two lateral longitudinal channels

1. ***Dorsal Haemocoelomic Channel.*** It is thin-walled non- contractile vessel running middorssally above the alimentary canal from one end of the body to the other. The haemocoelomic fluid flows from behind forward. The valves are absent. Anteriorily, it remifies in the 6th segment and supplies the anterior five segments. Posteriorly, it bifurcates in the 22nd segment; the two branches run ventrally around the rectum to join ventral sinus.

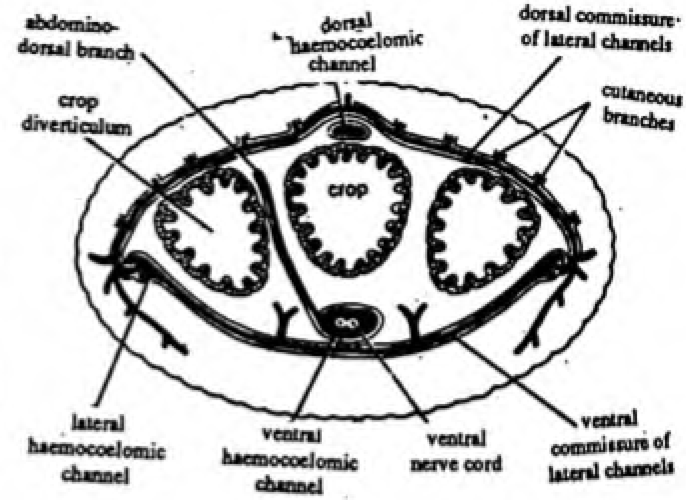


Fig. 43.12 *Hirudinaria.* T.S. body through dorsal and ventral commissures of the lateral haemocoelomic channels.

It gives two types of branches:

(i) *Dorso-laterals.* Two pairs of dorsolateral branches arise from the ventro-lateral side of the dorsal channel in each segment. Each branch runs outwards to form a capillary plexus in the dorsal and dorso-lateral regions of the body wall.

(ii) *Dorso-intestinals.* These are numerous small branches arising from the ventral side of the dorsal channels, all along its length. They supply the gut wall.

2. ***Ventral Haemocoelomic Channel.*** It runs below the alimentary canal in the mid-ventral region from anterior to the posterior end of the body. The flow of the blood is from anterior to the posterior end. It encloses the nerve-cord, cerebral ganglia, nerve-ring and sub-pharyngeal ganglion. It is wider than the dorsal sinus but there are no valves. All the arches are segmental.

(i) First pair of branches originate at the lavel of nerve-ganglion and give rise to two main branches: (a) *Ventral branches,* which is found on the ventro-lateral side of the body-wall. (b) *Abdomino-dorsal branch* which runs upwards between the diverticula of crop and supplies dorsolateral part of the body-wall.

(ii) The second pair is of nephridial branches, which are found in 11 segments i.e. from 12th to 22nd segment, having testis-sacs. Each branche forms 2 or 3 sets of saccules, the perinephrostomal ampullae, in which ciliated organs are enclosed and finally, passes out and gives off branches to lateral part of the body wall.

3. ***Lateral channels.*** There are two lateral haemocoelomic channels placed one on each side of the alimentary canal. They are wide and uniform in diameter. Their walls are thick, muscular and possess valves. The haemocoelomic fluid flows from posterior to anterior direction. They are collecting as well as distributing vessels.

Each lateral channel receives on its outer sides two branches, the latero-lateral and the latero-dorsal, and gives off on the inner side one branch, the latero-ventral, in each segment.

(i) *Latero-lateral.* The short latero-lateral is formed by the branches from the lateral region of the body wall and the nephridia. It joins the lateral channel at the level of the nephridial vesicle.

(ii) *Latero-dorsal.* It opens into the lateral vessel at the level of nephridium proper. This is a large branch and collects blood from the dorsal and dorso-lateral branches of both the sides are connected by a dorsal commissure, which runs transversely above the dorsal canal in the segments from 6th to 22nd.

Latero-lateral and latero-dorsal branches of each side are connected by a lateral commissure in each segment. These collecting branches possess valves at their openings in the lateral channel.

(iii) *Latero-ventral.* It arises from the inner side of the lateral channel in each segment. Immediately after its emergence it gives off a small branch to the nephridium and the ventral and ventrolateral region of the body wall. Soon it divides

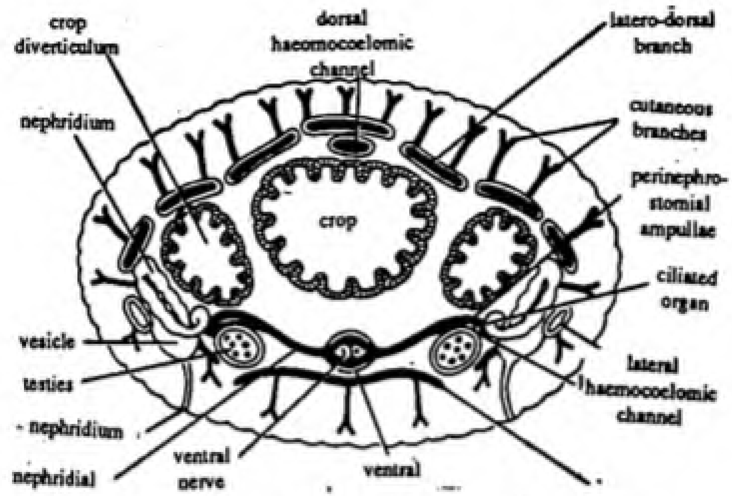


Fig. 43.13 *Hirudinaria.* T.S. body through nephridial branches.

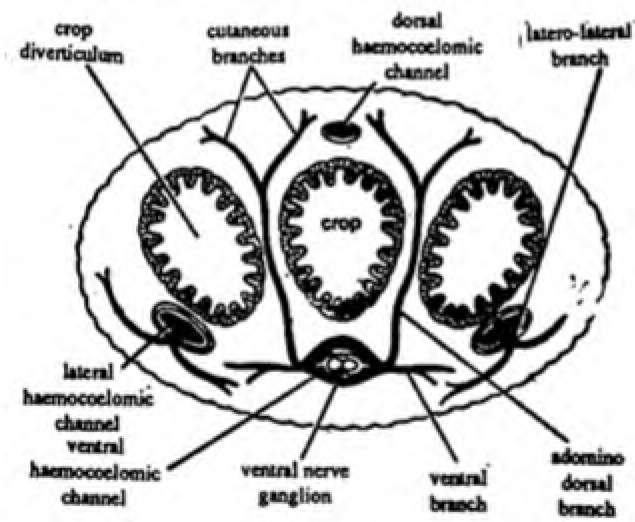


Fig. 43.14 *Hirudinaria.* T.S. body through dorso-abdominal branches.

into two branches. One of them is anterior branch, while the other is posterior branch. The two branches diverge from one another and unite with the corresponding branches of the other side below the ventral channel. This forms a characteristic rhomoboid figure, the ventral commissure of laterals. Eighteen such rhomoboids are found one in each of the segments from 6th to 23rd. The rhomboids of the adjacent segments are also joined together by three longitudinal intersegmental commissures. The latero-ventrals supply branches to the nephridia, alimentary canal, reproductive organs and ventral side of the body wall.

Course of circulation

Of the four longitudinal channels, the fluid in the dorsal and the two lateral channels move in anterior direction, while in ventral channel it moves in posterior direction. The dorsal and ventral are the distributing channels, while the laterals are collecting as well as distributing channels. All the channels are in direct communication with one another at the posterior end i.e. in 26th segment. The dorsal and ventral channels supply the haemocoelomic fluid to the body wall and dorsal surface of the alimentary canal. The ventral canal supplies the ventral and ventro-lateral parts of the body wall as well as the nephridia. The latero-lateral and latero-dorsal branches of the lateral channels collect the fluid from these parts. The latero-ventral branches supply the nephridia wall of alimentary canal, ventral body wall and reproductive organs.

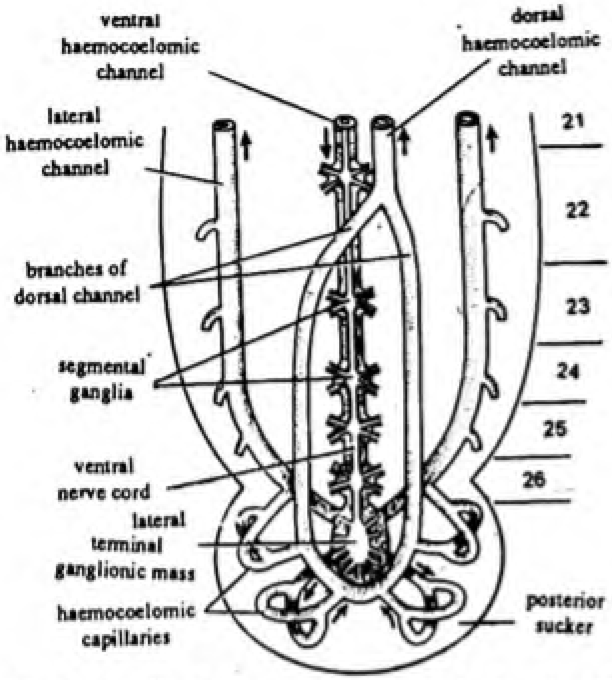


Fig. 43.15 *Hirudinaria* posterior end of body showing union of four longitudinal Haemocoelomic channels.

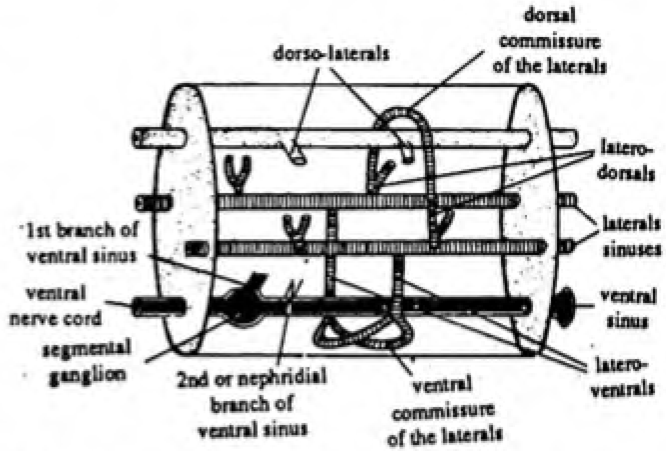


Fig. 43.16 *Hirudinaria* showing important channels.

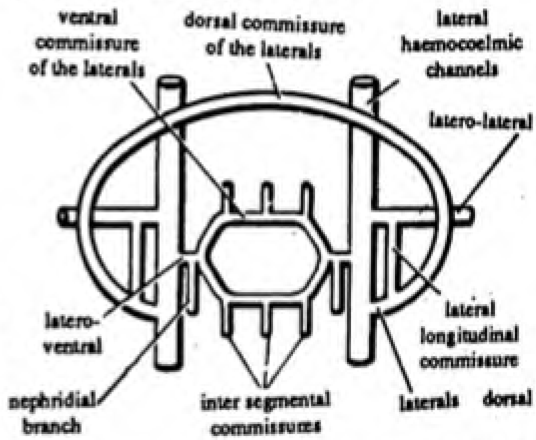


Fig. 43.17 *Hirudinaria*. Diagrammatic representation of the lateral channels and their branches in the segment in dorsal view.

RESPIRATORY SYSTEM

Leeches are devoid of special respiratory organs. The skin which has a rich supply of the haemocoelomic fluid act as respiratory surface for the exchange of gases. The epidermis acts as a permeable membrane through which the carbon dioxide from the haemocoelomic fluid diffuses out. Oxygen which is dissolved in water passess in the haemocoelomic fluid. For this purpose the skin is always kept moist and a copious secretion of mucous prevent it from drying. Some leeches such as *Branchellion* possess lateral out-growths of the body wall that actas gills.

EXCRETORY SYSTEM

The excretory system of leech comprises 17 pairs of segmentally arranged nephridia, situatea one pair in each of the segment 6th to 22nd. Of these the first 6 six pairs are located in segments 6th to 11th devoid of testis-sacs and are called the *pretesticular nephridia* and the remaining 11 pairs are the *testicular nephridia*. They remain in close association with the testis-sacs. The two types differ only in a minor respect.

Testicular nephridium. This is regarded to be a typical nephridium. Its shape is just like that of a horse-shoe and consists of seven parts:

1. Main lobe

2. Vesicle duct

3. Vesicle

4. Apical lobe

5. Inner lobe

6. Initial lobe

7. Ciliated organ

1. *Main lobe.* The main lobe is actually just like a horse-shoe and is situated in the ventro-lateral position between the adjacent caeca of the crop. It forms the major part of the nephridium and consists of two unequal limbs, out of which anterior is long and the posterior limb is small.
2. *Vesicle duct.* The vesicle duct is a narrow tube that starts from the inner end of anterior limb of the main lobs, runs backwards alongside the vesicle and opens into the vesicle near its hind- end.
3. *Vesicle.* The vesicle is a very large oval sac lying behind the rest of the nephridium and closely applied against the ventrolateral surface of the body wall, and opens to the exterior through a rounded aperture, the ***nephridiopore***.

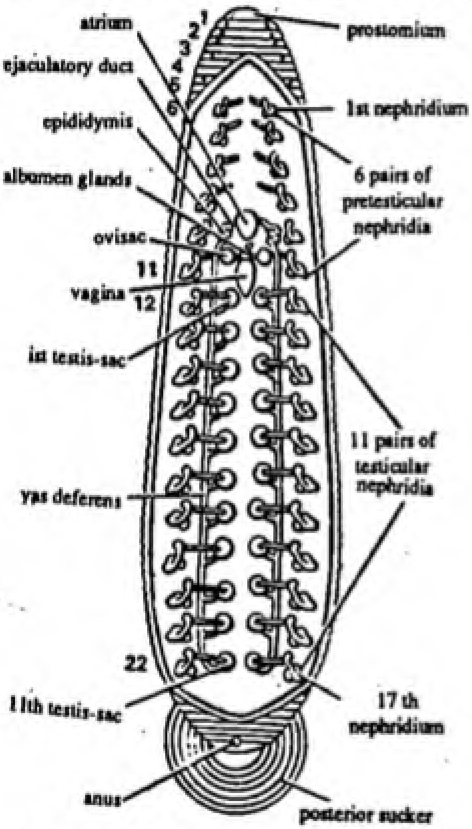


Fig. 43.18 *Hirudinaria* showing reproductive organ and nephridia.

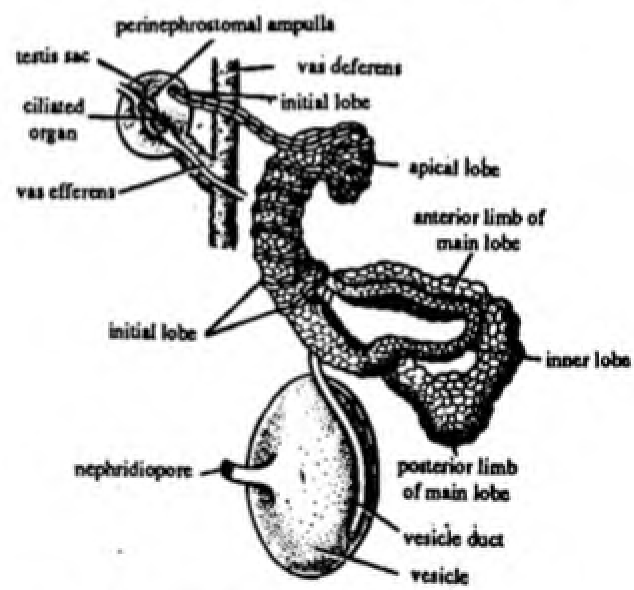


Fig. 43.19 *Hirudinaria.* Testicular nephridium.

4. *Apical lobe.* The posterior limb of main lobe is continued anteriorly into an apical lobe, situated antero-posteriorly beneath the crop. It is thick and stout and its anterior end is swollen and bent upon itself like the head of a walking stick. The cells lining the apical lobe are large with regular intracellular canals.
5. *Inner lobe.* Projecting from the anterior and the posterior limbs of the main lobe is found a short inner lobe situated in the concavity of the main lobe and running along the side of the apical-lobe for about half its length.
6. *Initial lobe.* The testis-lobe or the initial lobe is a long, narrow, transparent and cord-like structure, formed of a single row of elongated tubular cells and closely twined around the apical lobe. Its posterior end joins the main lobe, while the anterior end runs inwards and reaches over the testis sac of its own side, where it ends blindly close to the perinephrostomial ampullae. The intracellular canal of the initial lobe gives off many diverticula in each cell.
7. *Ciliated organ.* The ciliated organ corresponds to the funnel or nephrostome of a typical annelid nephridium and each consists

of

(i) a central reservoir, a perforated chamber, appearing more or less spongy, with an outer wall formed of a single-layer of cells and a central mass of connective tissue cells, the seat of manufacture of the coelomic corpuscles and (ii) ciliated funnels. Numerous funnels, each fitting into a pore of the reservoir by its narrow proximal part, the neck. They cover the reservoir from outside. Each funnel is like an ear-lobe, with about one-fourth of its margin incomplete along one side. The distal end is ciliated and broad.

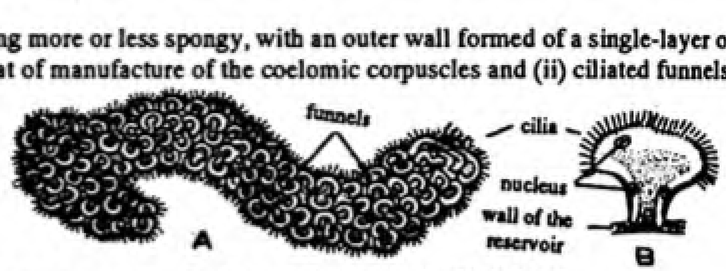


Fig. 43.20 *Hirudinaria*. A—Ciliated ordan, B—Single funnel.

In the adult *Hirudinaria* the ciliated organ has no connection whatever with the body of the nephridium although there is a distinct connection between the two in the embryo. In the adult it loses connection with the nephridium, gives up excretory function and associated with the haemo-coelomic system, for which it manufactures coelomic corpuscles and drives them into the haemo-coelomic stream.

Pretesticular Nephridia. The first six pairs of nephridia lying in segments from 6th to 11th have no relation with the testis sacs, since these are absent in these segments. Therefore, these are devoid of haemocoelomic ampullae and the ciliated organs. In other details these resemble the testicular nephridia.

Physiology of Excretion

The nephridium proper is truly excretory in function and serves to eliminate excess of water and nitrogenous wastes, (mostly ammonia and small quantities of urea). The nephridium is profusely supplied with branches of haemocoelomic channels. Its gland cells separate the waste products from the haemocoelomic fluid. The excretory fluid is finally collected into the terminal vesicle to be discharged to outside through the nephridiopore.

Several workers have also attributed an excretory function to the botryoidal tissue, the intracellular capillaries of which communicate with the haemocolelomic vessels.

NERVOUS SYSTEM

The nervous system satisfies the usual pattern of Annelida. It consists of three parts.

1. Central Nervous System,
2. Peripheral Nervous System, and
3. Sympathetic Nervous System.

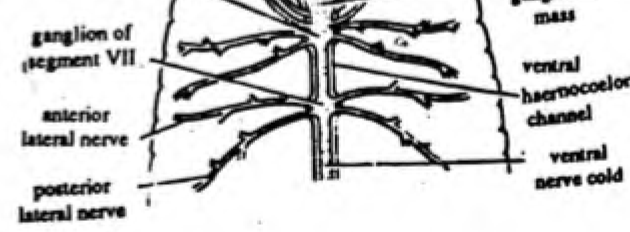


Fig. 43.21 *Hirudinaria*. Nervous system; in anterior region of body.

1. **Central Nervous System.** The entire central nervous system lies within the ventral haemocoelomic channel and consists of five parts-(i) cerebral ganglia, (ii) peripharyngeal connectives, (iii) sub-pharyngeal ganglionic mass, (iv) ventral nerve cord, and (v) terminal gangolionic mass.

(i) *Cerebral ganglia.* A pair of fused cerebral ganglia form a small brain situated above the pharynx just behind the median dorsal jaw in the 5th segment.

(ii) *Peripharyngeal connectives.* They start from the sides of the brain and pass downwards along the sides of pharynx to meet the sub-pharyngeal ganglionic mass.

(iii) *Sub-pharyngeal ganglionic mass.* Ventrally the

peripharyngeal connectives unite to form the subpharygeal ganglionic mass which lies below the pharynx exactly opposite to the cerebral ganglia. It is composite structure of more or less triangular shape, apex of the triangle pointing backwards formed by the fusion of four pairs of ganglia.

(iv) *Nerve-cord.* From the apex of subpharygeal ganglionic mass arises the ventral nerve cord. It runs along the mid-ventral line from 6th to 26th segment. Although it appears single, it is really double as both are surrounded by a common sheath the neurolemma. The ventral nerve cord carried 21 well formed ganglia, each located in the first annulus of its own segment. Posteriorly, the ventral nerve cord ends in a large ovoid terminal ganglionic mass, situated within the posterior sucker. It is formed by the fusion of seven pairs of embryonic ganglia of the lasts seven segments that constitute the posterior sucker.

2. **Peripheral Nervous System.** It consists of several paired nerves which are originated from the central nervous system and innervate all parts of the body. A pair of stout nerves arise from the brain which run forward to supply the first pair of eyes, the prostomium and the roof of the buccal chamber. The subpharyngeal ganglionic mass gives out four pairs of eyes and also to segmental receptors of the first five segments, roof of the buccal cavity and the muscles of body wall. From each ganglion of ventral nerve cord arise two pairs of stout nerves, the anterior laterals and posterior laterals. The anterior laterals arise from the anterior part of the ganglion, branch and innervate the vas deferens, nephridium, the nephridial vesicle, muscles of body wall, ventral nerve receptors and two outer dorsal receptors of their own side. The posterior laterals arise from the posterior part of ganglion just behind the anterior laterals. The posterior lateral branches innervate the viscera, median dorsal region of the body wall and the central pair of the dorsal segmental receptors. The terminal ganglionic mass sends off several nerves supplying the receptor organs and other structures found within the posterior sucker.

3. **Sympathetic Nervous System.** It consists of a nerve-plexus, situated beneath the epidermis within the muscles and the wall of the alimentary canal. It is connected on one side with the peripharyngeal connectives and on the other with certain multipolar ganglionic cells, which are irregularly distributed on the nerveplexus of the wall of the alimentary canal.

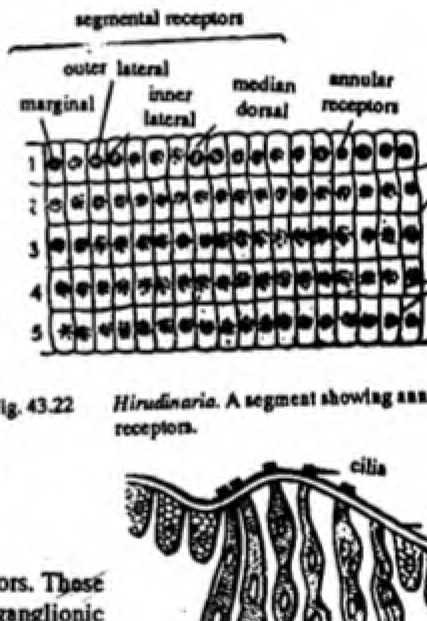


Fig. 43.22 *Hirudinaria.* A segment showing annular and segmental receptors.

SENSE ORGANS OR RECEPTOR ORGANS

The sense-organs or the receptor organs of *Hirudinaria* are especially modified epidermal cells. There are four types of receptor organs:

1. Nerve endings
2. Annular receptors
3. Segmental receptors
4. Eyes.

1. **Nerve endings.** These are the simplest and most numerous receptors. These are found between the epidermal cells all over the body with their ganglionic cells situated beneath the epidermis. These are simply the ends of nerve fibres. These organs are probably sensitive to chemical stimuli i.e. changes in the surrounding water. They, thus, act as chaemoreceptors.

2. **Annular receptors.** These are in the form of minute papillae, formed of flatenned overlapping epidermal cells. Their proximal ends are connected with the nerve fibres while the distal ends project out of the integrument. About 36 annular receptors are found to be equally distributed on the dorsal and ventral sides in each annulus. These form transverse rows across the middle of the annulus. The annular receptors are tactile in function or tangorecetors.

3. **Segmental receptors.** These are small whitish elliptical papillae borne upon the first annulus of each body segment, four pairs dorsally and three pairs

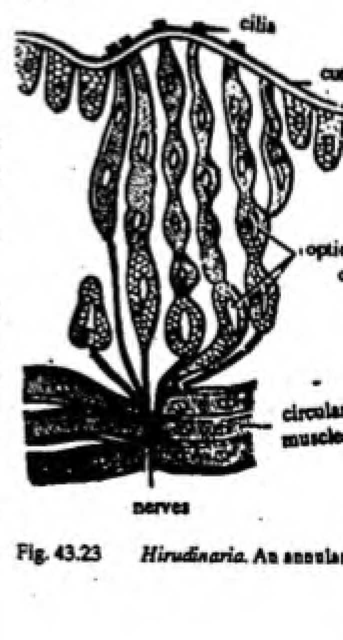


Fig. 43.23 *Hirudinaria.* An annular receptor in V.S.

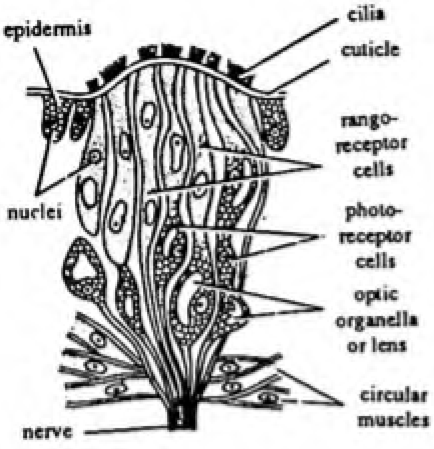


Fig. 43.24 *Hirudinaria*. A segmental receptor in V.S.

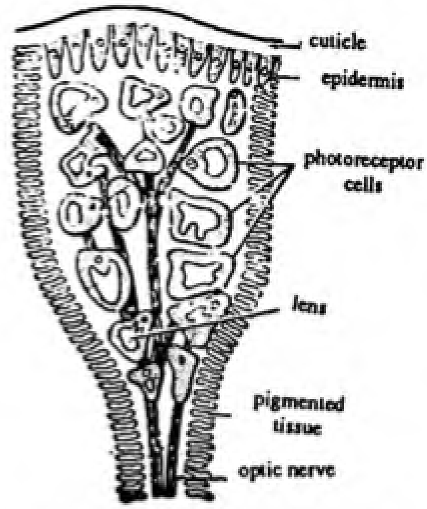


Fig. 43.25 *Hirudinaria*. V.S. of eye.

ventrally. Each receptor consists of two types of cells-tactile cells or tangoreceptors and light- sensitive cells or photoreceptors. There are 5 to 10 long, slender tactile cells, separated from one another and provided with hair-like processes at their outer free ends. The light- perceiving or the photoreceptor cells, found only in the dorsal receptors, contain a cresentic hyaline substance, the optic organelle or lens, in their cytoplasm. Each receptor receives a nerve branch and functions both as tangorecepetor and photoreceptor.

4. **Eyes.** There are five pairs of eyes lying in a semicircle of black spots on the dorsal surface of the anterior sucker, one pair in the first annulus of each of the first five segments. Each eye is cylindrical or cup-like in shape with its long axis perpendicular to the body surface. Each eye consists of a long pigmented cup covered externally by transparent epidermis and cuticle forming a cornea. Inside the cup are refractive cells arranged in several longitudinal rows. Each refractive cell contains a crescentic hyaline substance, the optic organellae or lens surrounded by a very thin peripheral layer of cytoplasm containing a small rounded nucleus. An optic nerve enters each eye basally and runs along its median axis distributing branches to all photoreceptor cells.

The eyes are directed in different directions and each can receive light from only one direction. It is not yet known whether images of objects are formed in the eyes. However, it is presumed that eyes can only distinguish light from darkness and can locate the direction of the source of light.

On the basis of their metameric arrangement and histological structure, *Whiteman* regards the eyes to be serially homologous with the segmental sense organs. Moreover, the segments with eyes lack the usual segmental receptors.

REPRODUCTIVE SYSTEM

Leeches are hermaphrodite i.e., male and female reproductive organs are found in the same individual.

Male Reproductive Organs. Male reproductive or generative organs consist of the following structures:

1. Testis-sacs
2. Vasa deferentia
3. Vasa efferentia
4. Epididymis
5. Ejaculatory duct

6. Atrium.

1. *Testis sacs.* Testis sacs are eleven pairs of small, spherical or rounded vesicles found one pair in each of the segments from 12th to 22nd. These are located one on either side of the ventral nerve cord. From the wall of each testis sacspermatogonia are budded off which develop into spermatozoa.

2. *Vasa efferentia.* The spermatozoa pass from each testis sac into a short sinuous duct, the vas efferens, which arises from the postero-lateral border of the testis sac and runs outwards to join the common vas deferens of its side. All the vasa efferentia of one side open into the common vas deferens of that side.

3. *Vasa deferentia.* There are a pair of slender longitudinal ducts running forward, from twenty-second to the eleventh segment, lying along the ventral body wall on either side of nerve cord. Each vas deferens is enclosed within a tubular coelomic space which contains amoeboid corpuscles similar to those of the haemocoelomic fluid.

4. *Epididymis.* The distal end of each vas deferens in the 10th segment widens into a coiled mass which is termed as epididymis. This is said to store sperm brought from the testis sacs.

5. *Ejaculatory duct.* Anteriorly, from the inner side of the epididymis arises a short narrow ejaculatory duct. It runs inward horizontally and joins the fellow of opposite side to form an atrium.

6. *Atrium.* The ejaculatory ducts of the two sides join a median pyriform sac, the atrium, extending into the 9th and 10th segments, and opening outside by the male genital pore. The atrium consists of two parts-a vase-like broad anterior part called the prostate chamber and a neck-like narrow posteriorly directed part, the penis sac. The prostate chamber has thick muscular walls which are covered externally by numerous unicellular prostate glands.

The penis-sac is the posteriorly directed narrow neck-like highly muscular part of the atrium which contains a coiled filamentous tubular penis. It helps in copulation and transference of spermatophores into the vagina of other leech.

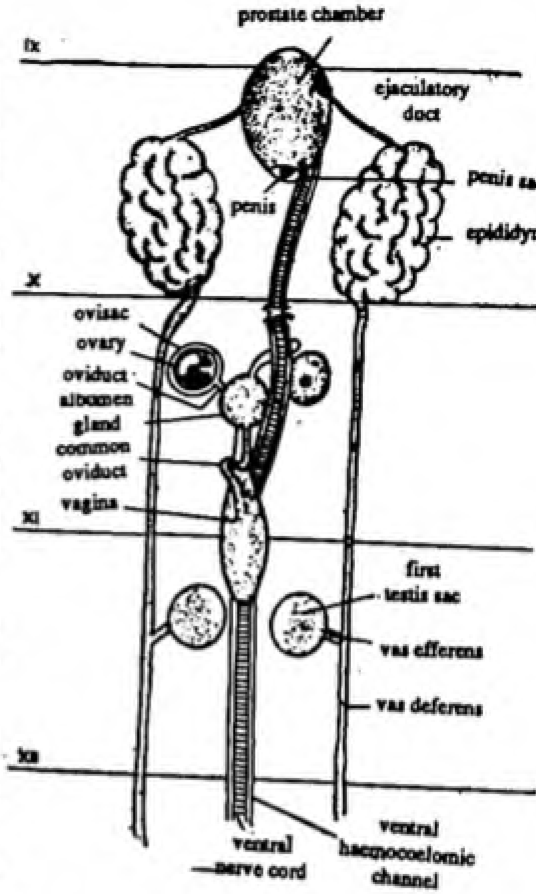


Fig. 43.26 *Hirudinaria.* Reproductive system.

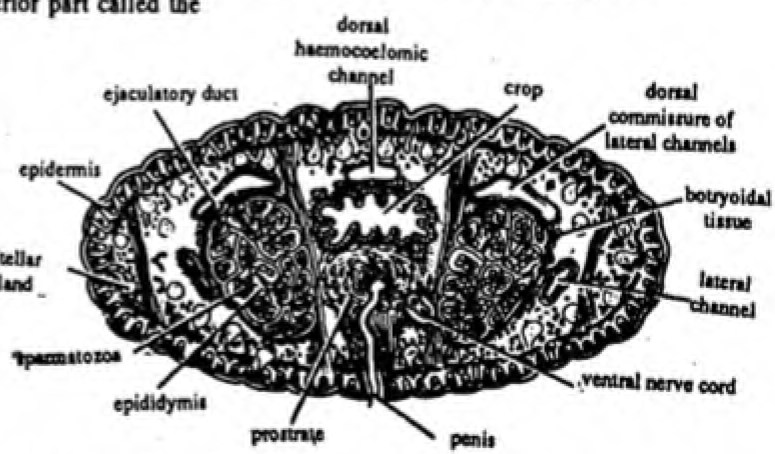


Fig. 43.27 *Hirudinaria.* T.S. body through epididymis, prostate and penis sac.

Female Reproductive Organs. The female reproductive system includes:

1. Ovisacs

2. Ovaries

3. Oviduct

4. Common Oviduct

5. Vagina

6. Albumen glands

1. *Ovisacs.* There is a pair of ovisacs situated ventro-laterally in the 11th segment, one on either side of ventral nerve cord. Each ovisac is a hollow structure filled with coelomic fluid, containing an ovary.
2. *Ovaries.* A pair of ovary, each enclosed inside an ovisac. Each ovary is a delicate, coiled and filamentours structure which contains many nuclei. The ova are formed by the budding from the wall of ovary.
3. *Oviducts.* From the base of each ovisac a narrow oviduct arises which runs inward and backward. The right oviduct passes below the ventral nerve cord and joins with that of the left to form a common oviduct.
4. *Common oviduct.* The common oviduct is a mid-ventral type having its posterior part open folded and opening into vagina.
5. *Vagina.* It is a large and pear shaped structure, lying ventrally in the posterior part of the 11th segment. It enlarges considerably during the breeding season. It is continued anteriorly into a duct that opens out at the female genital pore. The female genital pore lies on the ventral side in the groove between the second and third annuli of the segment 11.

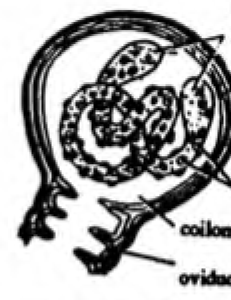


Fig. 43.28 *Hirudinaria.* An ovisac showing ovary.

6. *Albumen glands.* The place of the origin of common oviduct is covered by a thick layer of unicellular glands, the albumen glands, opening into the common oviduct.

The ova, budded off from the ovaries, pass through the oviducts into the vagina, where they remain till fertilization. The ova are coated with the albumen from albumen glands. Fertilization takes place in vagina. Fertilized ova are discharged into a cocoon for further development.

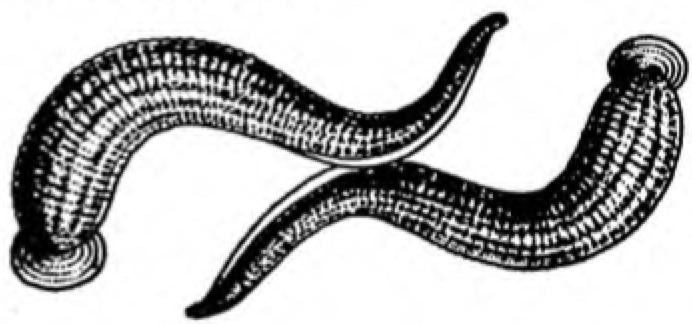


Fig. 43.29 *Hirudinaria.* Two leeches lapulation.

COPULATION AND FERTILIZATION

Copulation takes place in March and April. It may occur in water or on land and lasts for about an hour. Two leeches come in contact by their ventral surfaces in head to tail position, so that the male genital pore of one lies against the female genital pore of the other. Each copulant protrudes its penis and passes it into the female genital pore of the other to shed sperms in the vagina. Thus cross-fertilization occurs.

COCOON FORMATION

The cocoon is formed in the month of April to June after copulation. The cocoon is secreted in the form of snow-white, frothy girdle by the glandular skin of 9th, 10th and 11th segments. It is always formed during breeding season. After the cocoon is formed, clitellar glands secrete an albuminous fluid, which is deposited in the cocoon with the fertilized ova. The cocoon is then passed over the head of each individual. Leech then withdraws its anterior end backwards by rhythmic movements. When the prostomial region of the worm comes in contact with the anterior end of the cocoon, prostomial glands secrete a kind of plug which seals the anterior part of the cocoon and is called anterior polar plug. The leech goes on withdrawing its anterior end backwards till the prostomial region comes in contact with the posterior end of cocoon. There, it also secretes the posterior plug. After the posterior plug is completed, the leech shakes off the cocoon, which is laid in a moist place by the side of a pond or pool but never in water. Cocoon becomes hardened on exposure to the air. Its colour is light-yellow or amber and it is barrel-shaped. It measures about 25 to 30 mm. in length and 12 to 15 mm. in diameter. The wall of cocoon consists of an inner, thin, tough membrane and an outer thick, spongy layer. There are also anterior and posterior polar plugs on the anterior and posterior sides respectively.

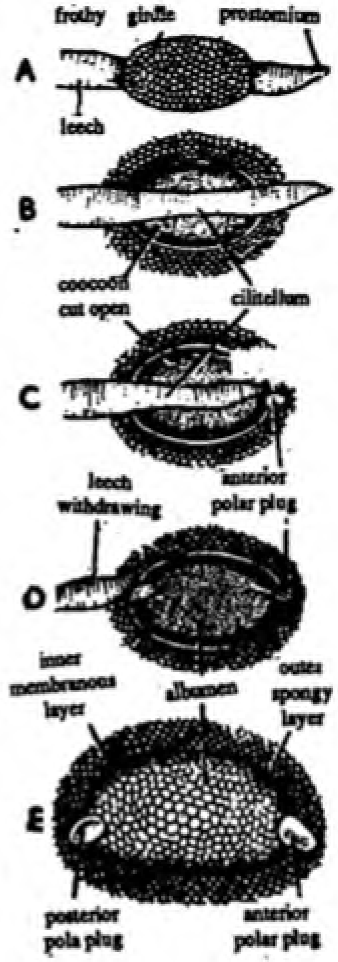


Fig. 43.30 *Hirudinaria.* Various stages of cocoon formation.

DEVELOPMENT

Development of fertilized egg takes place within the cocoon and takes about 15 days. In each cocoon 1-24 embryos develop. The development occurs at the cost of albumen. On completion of development.

44

ARCHIANNELIDA

The name Archiannelid was first of all suggested by *Hatschek* in 1893. The group representing an assemblage of marine, elongated and thread-like animals without setae or parapodia. Formerly they were considered as primitive forms, from which another annelids might be derived. The marine animals, included in this group, are *Polygordius* and *Protodrilus*. In addition to these main representative types different authors have included a number of other animals in this group i.e. *Sedgwick* included four other animals as: *Dinophilus, Saccocirrus, Aelosoma* and *Histriodrilus Beriham* in C.N.H. included only *Dinophilus* and excluded all others. On the other hand *Parker* and *Haswell* included *Dinophilus, Sacocirrus* and *Norilla*.

As representative type of Archiannelida, *Polygordius* and *Protodrilus* may be taken as examples and the point of differences in which they differ from other forms can be delted later.

CHARACTERISTICS OF ARCHIANNELIDA

Chief characteristics of Archiannelida as shown by *Polygpordius* and *Protodrilus* are as follows:

1. These are elongated, thread-like marine worms with cylindrical body.
2. Parapodia, setae, gills etc. are absent.
3. External segmentation indistinct but internal segmentation is complete and the segments are represented by coelom.
4. Small prostomium overhang the mouth and bears a pair of tentacles and a pair of ciliated pits. Prosatomium is followed by large peristomium or oral-segment which constitute the first segment of body.
5. Body is devoid of circular muscle fibres.
6. Nervous system is situated in epidermis and is not separated out from it. The ventral nerve cord lies in epidermis, is without ganglionic swellings. In *Protodrilus* two ventral nerve cords are widely separated from one another by the ventral groove, though in *Polygordius* the two ventral nerve cords are fused together along the length.
7. The right and left coelomic cavities are separated by dorsal and ventral septa. Oblique longitudinal septa are present which pass across the body cavity on each side, from the region of ventral nerve cord to the lateral body wall and in *Prododrilus* body cavity is traversed by space reticulum.
8. A pair of simple nephridia are present in each segment which open internally in segment preceeding in which the body of nepliridium lies.
9. Both dorsal and ventral blood versels are present in corresponding mesenteries but both are non-contractile. The colour of blood may be red, yellow, green or may be colourless depending upon the species.
10. Germinal cells are developed from coelomic epithelium and are discharged in body - cavity from where they pass out. Definite genital ducts are absent.
11. Sexes separate or united.
12. A typical trochophore larva, known as Loven's larva, is found in *Polygordius*, but it has not been reported from *Protodrilus*.

DEVELOPMENT OF POLYGORDIUS

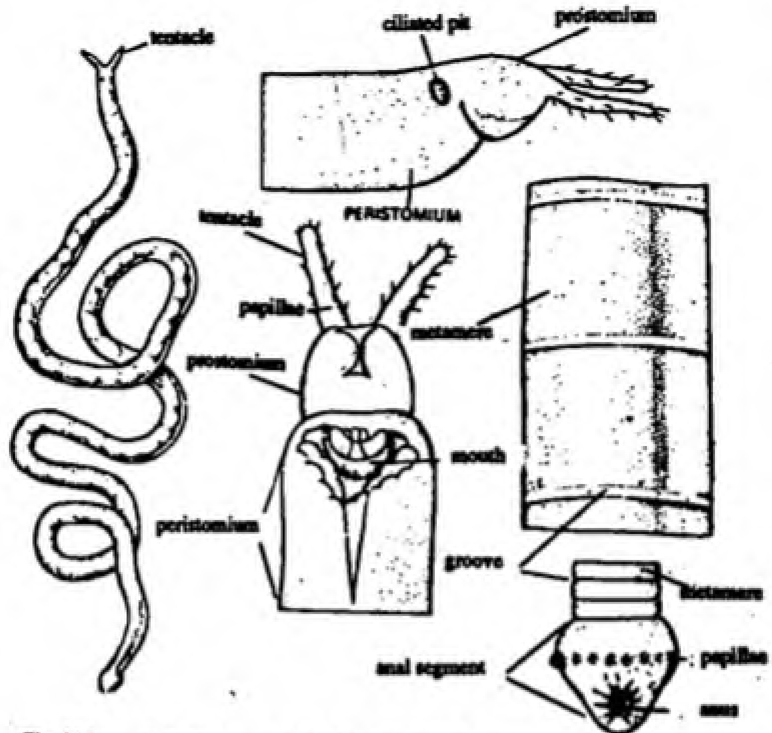


Fig. 44.1 *Polygordius,* external features. A—Entire worm, B—Side view of anterior end, C—Ventral view of anterior end, D—Segments of the trunk, and E—Anal segment.

The larva of *Polygordius*, as it comes out from the body, is in the form of typical trochophore larva known as Loven's larva.

The larva is typically trochophore but is some what reduced in form. It has the appearence of a complete and wild cone united by the bases.

The larva bears a double row of cilia, the pre-oral cilia and post-oral cilia. The lateral girdle of cilia is somewhat weaker. Mouth lies at one side of larve betwen two ciliary bands whereas the anus lies at the apex of post-oral cone and is surrounded by and girdle of cilia. The apical plats is present on the top of preoral cone and bears eye spot. There is a pair of mesoblastic bands at the hinder nephridia. Alimentary canal is divided into stomodaeum, enteron and proctodaeum. The alimentary canal is separated from body wall by a vast space represented by blastocoel.

Fig. 44.2 *Protodilus.*

METAMORPHOSIS

During metamorphosis posterior part of body elongates and, mesoderm becomes separated to form somites, forming trunk region of the adult. This elongated region grows due to active growth of post-oral cone and gets segmented both, internally as well as externally. The anterior part of larva perish in adult though it greatly reduced and forms the head of adult. The base of apical plate forms the brain and thickening of epidermis on ventral side is termed as ventral nerve cord. As development proceeds the mesoblastic somites become rolled out to form mesoblastic cavities.

Polygordius	*Protodrilus*
1. Found in sand of European Seas.	1. It occurs in sand of European inlands, sea-lake at Faro near Messina.
2. External segmentation is shown by faint grooves.	2. External segmentation is marked by ciliated grooves.
3. A median ciliated groove is absent.	3. A median ciliated groove is present.
4. Ventral nerve cords are fused along mid-ventral line.	4. The ventral nerve cords are widely separated from one another being situated on either side of mid-ventral groove.
5. A short invisible buccal region is present followed by oesophagus.	5. Buccal region is not visible but there is a 'U' shaped muscular tube placed ventral to oesophagus and opens into it, which is eversible help the animal in burrowing and swallowing mud.
6. Coelom brightly coloured and devoid of any reticulum.	6. Body cavity is lined by a network of fibres which are, however, few in number forming reticulum.
7. Sexes are separate and the testes and overies are confined to posterior segments of the body. Ova and sperms are escaped from body by its rupture, beacuse gonoducts are absent.	7. The animal is bisexual. Testes are present in the posterior segments. Ova are released by the rupture of body wall while sperms through the nephridia.

Dinophius

Dinophilus is included in class Archiannelida by several workers. Its structure is much similar to those of *Polygordius* and *Protodrilus*. It is a small worm found in English Channel on sea weeds during spring. It consists of a head constituted by a pre- oral chambers followed by a trunk which is, in an immature animal, distinct to show 5 or 6 segments. Each segment is demarked externally by one or two ciliary rings. Pre-oral lobe of prostomium is broad and bears a pair of simple eyes, one or two ciliated pits. Tentacles are absent.

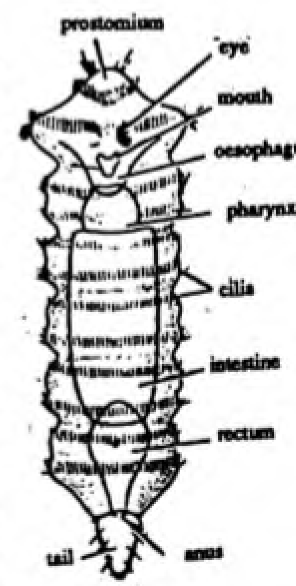


Fig. 44.3 *Dinophilus.*

The alimentary canal is straight and ciliated. There is a ventral muscular protrusible organ opens into oesophagus. The nerve cord is continuous with epidermis and consists of a brain or ganglion in prostomium and a pair of widely separated nerve cords. The two ventral nerve cords sometimes show incipent segmental ganglian.

Body is traversed by a net work of connective tissue in which sex calls are present. Five pairs of protonephridia opening on the surface of the body. Internally no inter-segmental septa or dorsal or ventral mesenteries of ducts.

Sexes are separate, the male being much smaller than female. The part of nephridia in males are connected with testes and act as seminal vesicle and the male genital products are passed through the common aperture formed by the union of 5 pairs of nephridia before they open out. A median penis is present which passes through the body wall. The young ones are hatched as trochophore larva.

Saccocirrus

It resembles *Protodrilus* in many respects so that it must be placed close to this animal. Following characters show

resemblence with *Protodrilus*:

1. Presence of ciliated ring on head.
2. Presence of oblique septa.
3. Presence of dorsal and ventral mesenteries.
4. Presaence of widely separated nerve cord which is in contact with epidermis.

The only point of difference is a presence of segmentally arranged setae, which give it a planarian appearence.

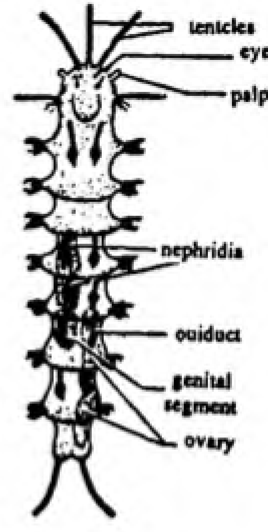


Fig. 44.4 *Nerilla.*

Aelosoma

It is often included among oligochaetes, but from its characteristics it seems desirable to place it among annelids of uncertain position. It is a small, transparent fresh water worm with a loose and uncertain body.

1. The prostomium is ciliated ventrally and ciliated pits are present.
2. Four setae are present in each segment behind prostomium.
3. Epidermis contains coloured cells, circular and longitudinal muscles are present but both are very thin.
4. One pair of nephridia present in each segment.
5. Central nervous system possesses a cerebral ganglion or brain which is continuous with epidermis but not followed by ventral nerve cord in trunk region.
6. Reproduction is by fission. Gonads are present but gonoducts are absent. The male gametes or sperms pass through a pore on the ventral side of 6th segment. In addition spermathecae are present in segment 3-5.
7. Bundles of setae are present on body wall.

Nerilla

Nerilla is included among Archiannelida by *Parkar* and *Haswell*. These are minute marine worms with segmentally arranged parapodia. Their position, however, is extremely doubtful whether it should be annelid or archiannelid.

AFFINITIES OF ARCHIANNELIDA

The main animals which are included in this class are *Polygordius* and *Protodrilus*. These are definitely annelids as is shown by the fact that they have segmented body, intersegmental septa and segmentally arranged nephridia.

But they may be regarded as primitive members of the phylum because of:

1. Absence of setae or parapodia.
2. Primitive condition of nerve cord which is in contact with epidermis.
3. Even the Ist segment bears the excretory organ.
4. In the nerve cord the ganglia are not fully formed.
5. The layer of circular muscles in the body wall is not developed as is present in higher annelids.

Due to above characteristics *Polygordium* and *Protodrilus* must be placed in separate class from rest of the annelids i.e. in class Archiannelida. As regards the other members which are included by some authors in class Archiannelida, *Saccocircus* is closely related and allied to the above mentioned animals due to presence of the segmented body, nephridia and prostomial tentacles. It also shows the primitive characters of central nervous system, which is in contact with the epidermis and presence of the ciliated pits on the head. The only point of difference in which it differs from the two typical genera, *Protodrilus* and *Polygordius*, is that *Saccocirrus* presents lateral caecae in each segment in which it resembles higher animals, but even in this

character it is very close to *Protodrilus*. As regards *Dinophilus* it is included in Archiannelida due to presence of a body which is extraordinary segmented specially in young stage. But it shows much structures than even that of *Protodrilus* and *Polygordius*. It differs from them in following respects:

1. Absence of tentacles.
2. Body without coelomic or oblique septa.
3. Locomotion by ciliary bands.
4. Absence of vascular system.
5. Body is traverced with network of reticulum.

Thus on the whole it seems advisible to place it in separate sub- class. In Archiannelida the typical forms are like *Polygordius* and *Protodrilus*.

EXCRETION IN ANNELIDA

Excretion is the process by which the metabolic waste products are thrown out of the body. In annelids the process is performed by special organs called nephridia (*Lankaster*, 1877). These nephridia exist a variety of modification, not only in different species, but also in the different segments of the body of same individual. In addition to nephridia the chloragogan cells, coelomoducts etc. may play accessory role in excretion.

EXCRETION IN POLYCHAETA

There are two types of ducts which communicate the coelom to exterior. These are

1. Nephridia

2. Coelomoducts.

A variety of combination exists between the two above and this aspect has seen studied by *Goodrich* (1940), who also traced the evolutionary status.

Types of Nephridia. There are two types of nephridia:

(i) ***Protonephridia.*** It is the primitive type of nephridium. It opens to the exterior by an opening called nephridiopore. But internally, it terminates in the coelom as a blind tube. Internally the tube branches. The closed ends of branches bear a number of solenocytes which help in excretion. The solenocyte resemble the flame cell. It has a cavity surrounded by a mass of cytoplasm with a nucleus in it. The lumen of these cells enclose a long, vibratile flagellum (in each). Excretory fluid enters through the walls of the nephriidial tubules which are internally ciliated. The fluid is driven into the lumen of the nephridium by the flagellum and forced to the exterior through the nephridiopore. The protonephridia are found in *Glycera, Phyllodoce, Nephthys* etc.

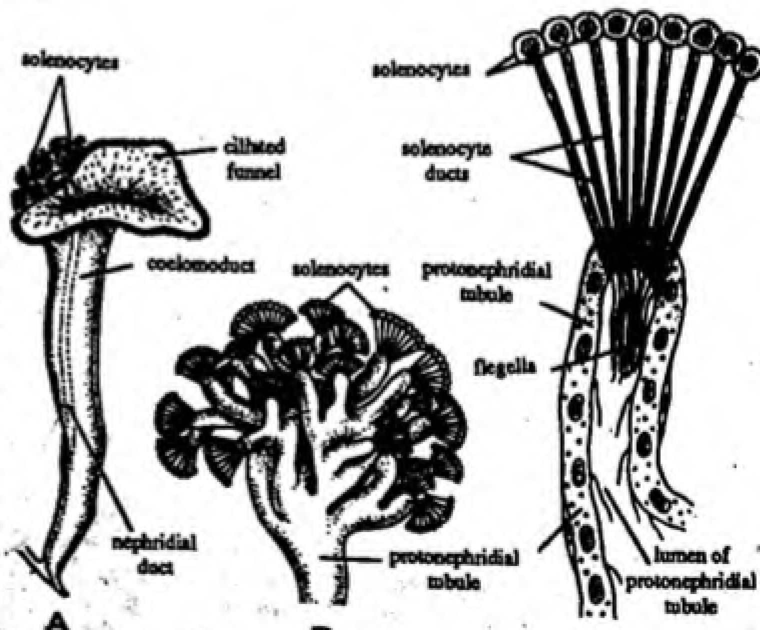


Fig. 45.1 Protonephridium and coelomoduct in *Phyllodoce paretti.* A—Relation of protonephridium and coelomoduct, B—, Branched end of protonephridium, C—Solenocytes of one protonephridial branch.

(ii) ***Metanephridia.*** These nephridia have two openings. One end of the nephridium opens into coelom by a funnel like opening, the nephrostome and the other end opens out by nephridiopore *Coelomoducts.* These are segmentally arranged, wide tubes developed as out pushing from

the coelom to the exterior. The coelom communicates to the exterior with the help of coelomoducts. They open into the coelom by a large ciliated funnel called coelomostome. Based on the combination occuring between nephridia and coelomoducts, *Goodrich* (1945) recognized following types of structures called nephromixia:

(a) *Protonephromixium.* This is formed by the coelomoduct becoming grafted on to the excretory canal of a protonephridium. These are seen in *Phyllodoce.*

(b) *Metanephromixium.* This is formed by the coelomoduct becoming grafted on to the open nephridiostome of a metanephridium. A good example is seen in *Hesione.*

(c) *Mixonephridium.* This is formed by complete fusion of the coelomoduct to the inner end of metanephridium so that the entire structure appears a simple formation with a large internal funnel formed by coelomoduct and its duct by the nephridium. Mixonephridia occur in *Arenicola.*

Ciliated Organs. A part of coelomoduct becomes separated off from the metanephromixia and becomes attached to dorso-lateral muscles as a ciliated organs. This keeps the coelomic fluid in circulation. Example *Neanthes.* These are not known to open externally.

In most polychaetes nephridium is a wide sac-like tube as in *Arenicola.* Its walls are covered with a dense net-work of blood vessels and acts not only as nephridial organ but also a gonadial duct.

Nephridia of *Neanthes* differ from most of the polychaetes and resembles to that of certain oligochaetes. It is a compact gland- like organ containing a much coiled tube. The funnel opens into anterior to the one in which the body of nephridium lies. The last part of the coil projects out of the body of the nephridia to the coil projects out of the body of the nephridia to the exterior at the base of parapodium.

Location and number. Generally the nephridia are present in almost all the segments of the body with the exception of a few on either side. But in *Arenicola*, there are only six pairs and in *Sternastis* only one pair occur. In tubicolous polychaetes the anterior nephridia are enlarged and the posterior are reduced. In the fan-worm, a single nephridial canal opens on the head.

The principle nitrogenous waste in polychaetes is ammonia. The waste diffuses from the coelomic fluid or the blood to the nephridial tubules and then transfered to the lumen to be removed to out side.

EXCRETION IN OLIGOCHAETA

Except *Paranis uncinata* all the oligochaetes have nephridia. The nephridia which are present are of metanephridial type possessing an internal pre-septal funnel or nephrostome, its tubule and forms a terminal nephridiopore.

With our present growing knowledge several corrections have been made in the classification of oligochaetes nephridia. *Stefenson* had recognized only eight types while *Bhal* classified them into thirteen types. *Bhal* has also discovered the enteronephric.

Bhals' classification is obviously far superior to those of earlier workers, since he took into consideration not only their size but also their structure, development and phylogenetic relationships.

The large nephridia are called *meganephridia* where as small are called as *micronephridia.* These are small as compared to meganephridia and are not related to septa. There is one another type known as *mesonephridia.* The mesonephridia can further be divided into *exonephric* (opening out-side the body) and enteronephric (opening into the alimentary canal.)

Holonephridia. These are generally large in size and did not undergo any division during their develop-

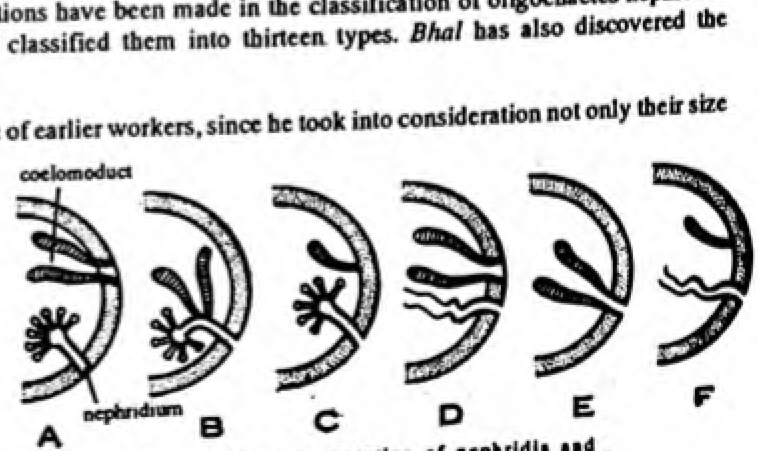


Fig. 45.2 Diagrammatic representation of nephridia and coelomoduct in various combinations in Polychaeta. A—Protonephridium and separate coelomoduct (*Vanadis*), B—*Protonephromixium* (Phyllodoce), C—Protonephridium and ciliated organs (Nephthyidae and Glyceridae), D—Metanephridium and separate coelomoduct (Capitellidae), E—Mixonephridium (*Arenicola*), F—Metanephridium and ciliated organ (Neries).

ment. The holonephridia can be divided into following types:

I. *Open exonephric holonephridia.* This type is found in *Lumbricus trestis.* The nephridia is divided into pre-septal funnel (nephrostome) and post-septal body. The body is divided into

(i) a long narrow tube

(ii) there is a short brownish tube which is ciliated

(iii) a wide part of tube and

(iv) muscular tube and reservoir.

II. *Open transtionally exonephric holonephridia.* These are found in *Allololesphora* species from 35 segments onwards but never in 1-34 segments. The nephridia unite to two longitudinal excretory canals running parallel to the alimentary canal. These canals unite at the opening of anus with the alimentary canal forming a median ampulla.

III. *Closed exonephric holonephridia.* These are found in *Chaetogaster.* These nephridia are 'U' shaped and without cilia and nephrostome.

Meronephridia. The nephridia breaks down or splits up during the course of development and are generally small in size. They can be classified into following types:

I. *One pair of open exonephric meronephridia.* These are as their name indicates, one pair in each segment. The example is *Megascolex.* The nephridia are small, compact with sac-like in appearence and a preseptal funnel (nephrostome).

II. *Paired cluster open exonephric meronephridia.* In the case of Dicogaster. They are found in three pairs, three nephridia on either side of nerve cord. *Vidyavati* (1941) found many pairs in *Megascolex.*

III. *Open transtionally enteronephric meronephridia.* This type of nephridia are seen in *Heplochaetella* from 3 segments onwards. The nephridia on either side joined by a pair of longitudinal excretory ducts as in transitional holonephridia, but the ampulla is totally absent. The canals open near the anus in alimentary canal.

IV. *Open enteronephric mega-mero-nephridia.* Due to large size of the nephridia attain, *Bhal* has considered them as mega-mero-nephridia. Since earlier workers were misled by their size. There is a free septal funnel or nephrostome. Body is composed of straight and twisted lobes. The canal opens into supra-intestinal excretory canal which runs above the alimentary canal and opens into alimentary canal. Examples: *Pheretima* and *Megascolex.*

V. *Closed exonephric meronephridia.* These are found in 5-9 segments of *Lampito.* Each nephridium has got its own tubule which opens into pharynx

Tufted nephridia. These nephridia originated either due to the incomplete branching of holonephridia or union of the terminal canals or ductules of mesonephridia. They are classified into following types:

I. *Open exonephric tufted nephridia.* They occur in the pre-clitellar and clitellar segments of *Pontoscolex* species. The number of nephridia varies being 80-100 in second segment and they gradually decrease in number.

II. *Closed exonephric tufted nephridia.* These are 9-10 pairs of tuft of nephridia occurs in each segments. Example is *Megascolex.*

III. *Closed enteronephric tufted nephridia.* They occur in 4, 5 and 6 segments of *Pheretima* and are often described as pharyngeal nephridia.

Chloragogen cells. In earthworm the intestine is surrounded by some yellow cells called chloragogen cells.

They take off nitrogenous waste products from the blood capillaries of the gut and deposit them as yellow granules called guanin in their cytoplasm. When fully loaded with waste products, they detach themselves from the gut wall and drop into the coelomic fluid. In the fluid they are consumed by the amoebocytes. The debris of these cells are wafted towards the nephrostome and are taken out by nephridial tubes. According to some workers chloragogan cells serve as store house for reserve materials.

Semal Van Gansen (1956) mentions that in terrestrial species of Oligochaeta, the silicates got from food material and soil are removed from the body and deposited in the chloragogen cells as waste products. *Liebman* (1946) describes that the eleocytes which are free cells into the coelom formed as a result of release of chlorgogen cells are laden with food reserve. However, *Semal-Van Gansen* regards eleocytes as degenerate chloragogen cells which are destroyed by phagocytic coelomcytes.

EXCRETION IN HIRUDINEA

In hirudinea the excretory organs are segmentally armaged nephridia. These are 17 pairs lying in segments 6-22. The anterior 6 pairs of nephridia are situated in segment 6-11 which are without testis sacs, hence called the pre-testicular nephridia. The posterior 11 pairs of nephridia are called testicular nephridia as they occur in segments 12-22, each of which contains a pair of testis-sacs.

Each nephridium is a horse-shoe shaped structure called main lobe. The main lobe has two limbs-an anterior-limb and a posterior limb. A lobe-like structure lies between the two called inner lobe. The posterior limb is continued forwards as the apical lobe. The anterior end of the apical lobe looks like the handle of walking stick.

There is a long hollow tube which coils around the apical lobe called initial lobe. One end of the initial lobe opens into the main lobe and the other ends blindly in the testis sac. From the inner end of the anterior limb arises a duct called vesicle duct. The vesicle duct leads into a vesicle. An excretory duct arises from the vesicle and opens out by an opening called nephridiopore.

Ciliated organ. Inside the perinephrostomial ampullae lies the ciliated organ. A ciliated organ has a central reservoir which is perforated, around which are innumerable ciliated funnels. The reservoir is a more or less spongy structure with an outer wall formed of a single layer of cells and a central mass consisting of connective tissue cells and corpuscles. Each ciliated funnel is like an ear-lobe, with about one-fourth of its margin incomplete along one side and is covered with outwardly directed cilia on its outer margin and inner surface. The ciliated organ manufacture coelomic amoeboid corpuscles. Ciliated organs are joined to nephridia in the embryo, but in the adult animal they have no connection with nephridia. This shows that originally the ciliated organ belonged to a nephridium, but in the adult, having no connection with the nephridium. It is not excretory but has become a part of haemocoelomic system for making corpuscles. Ciliated organs correspond to coelomoducts of Polychaeta and not to nephrostomes of nephridia.

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ARTHROPODA

CHARACTERS AND CLASSIFICATION

Phylum Arthropoda (Gr. *arthros* = joint; *pods* = foot) contains the great majority of the known animals, about one million species, and many of them are enormously abundant as individuals. It includes such common and well-known forms as the crabs, shrimps, insects, spiders, scorpions, ticks, centipedes, as well as a host of other less familiar forms. *Cuvier* (1800) placed all these animals together with Annelida under the group Articulata. *Van Siebold* (1845) separated Annelida from Articulata. Annelida were placed under class Vermes while the Crustacea, Arachnida and Insecta under an independent group, the Arthropoda.

General Characters

1. Arthoropoda are triploblastic, bilaterally symmetrical, metamerically segmented animals.
2. Body is covered with a thick chitinous cuticle forming an exoskeleton.
3. Body segments usually bear paired lateral and jointed appendages.
4. Musculature is not continuous but comprises separate striped muscles.
5. Body cavity is haemocoel. The true coelom is reduced to the spaces of the organs.
6. Digestive system complete; mouthparts adapted for various modes of feeding.
7. Circulatory system open with a dorsal heart, arteries and blood sinuses.
8. Respiration by general body surface, gills, tracheae or book- lungs.
9. Excretory organs are green glands or Malpighian tubules.
10. Nervous system with a dorsal nerve ring and a double ventral nerve cord.
11. Cilia are entirely absent from all parts of the body.
12. Sexes are generally separate and sexual dimorphism is often exhibited by several forms.
13. Fertilization is internal. Development is usually indirect through larval stages.
14. Parental care is also often will marked in many arthropods.

Phylum Arthropoda is divided into following classes:

Class I-Crustacea

Class II-Myripoda

Class III-Insecta

Class IV-Arachnida

CLASS - I. CRUSTACEA

1. The body is divisible into head, thorax and abdomen, when head and thorax are fused they form cephalothorax.2.

2. The exoskeleton is chitinous.
3. The body is metamerically segmented, bilaterally symmetrical and triploblastic.
5. Each segment bears paired and jointed appendages.
6. The body cavity is filled with haemolymph and known as haemocoel.
7. Respiration takes places either by the general body surface or by gills.
8. Excretion occurs by modified coelomoducts, which may take the form either of maxillary glands or antennary (green) glands.
9. These are unisexual except many Cirripedia and some Isopods.
10. The development is indirect.

Class Crustacea is divided into 7 subclasses

Subclass - 1. Branchiopoda

1. Body has varying number of segments.
2. Antennules are small, uniramous and usually unsegmented.
3. Compound eyes are present.
4. Thorax bear four or more flat, leaf-like respiratory appendages also help in filter feeding and locomotion.
5. Abdomen without appendages.
6. Parthenogenesis is common.

Subclass Branchiopoda is divided in three orders:

Order (i) Anostraca

1. The carapace is absent.
2. Eyes are stalked.
3. Antennae are uniramous, prehensile in male reduced in female.
4. Trunk elongated with 20 or more segments. Anterior 11 - 19 Segment bear appendages.
5. The caudal styles are unjointed.

   Example: *Branchipus, Streptocephalus, Artemia.*

Order (ii) Notostraca

1. A large dorsal shield-shaped carapace is present.
2. Eye are sessile i.e. stalkless.
3. Anteenae are reduced.
4. Anterior half of the trunk bears 35-70 pairs of appendages.
5. The caudal styles are many jointed.

   Example: *Apus, Lapidurus.*

Order (ii) Conchostraca

1. The carapace is present but divided in two portions or valves.
2. Antennae biramous and large.

3. Eyes are sessile.
4. Caudal styles are in the form of unjointed, curved claws.

   Examples: *Limnetis, Estheria.*

Order (iv) Cladocera

1. The carapaca bivalved, encloses the trunk but not the head and usually ends posteriorly in an apical spine.
2. Eyes are unstalked and united together.
3. Antennae biramous used for swimming.
4. Trunk segments 10-32, each with a pair of appendages.
5. Caudal styles are unjointed claw-like.

   Example: *Daphnia.*

Subclass-2. Ostracoda

1. Compound eye may or may not be present.
2. Carapace is bivalved and compressed which encloses entire body.
3. Head forms about half of the body.
4. Thorax usually bears only two pairs of cylindrical appendages.
5. Abdomen is reduced, without appendages and ends in a pair of caudal styles.
6. Antennules and antennae locomotory.
7. Manibles have a palp.
8. Larva is Nauplius.
9. Parthenogenesis is common.

Subclass Ostracoda is divided into following orders:

Order (i) Myodocopa

1. Marine Crustaceans.
2. Carapace with antennal notches.
3. Antennae biramous.
4. Trunk appendages two pair.

   Examples: *Cypridina, Concoecia.*

Order (ii) Cladocopa

1. Marine forms.
2. Carapace un-notched
3. Both pairs of antennae used in swimming.
4. Second pair of antennae with 2 branches.

   Example: *Polycope.*

Order (iii) Podocopa

1. Maine or freshwater
2. Carapace Unnotched.
3. Second antennae leg - like, clawed at tips.
4. Trunk appendages 2 pairs.

   Examples: *Cypris, Entocythere, Cythereis.*

Order (iv) Platycopa

1. Marine forms.
2. Carapace unnotched.
3. Both pairs of antennae large but not used for swimming, second pair flatenned.
4. Trunk appendages single pair.

   Example: *Cytherella.*

Subclass 3. Mystacocardia

1. Primitive marine forms.
2. Size microscopic, cylindrical.
3. Antennules and antennae long, prominent.
4. Eyespots, compound eyes absent.
5. Thorax 4-segments, each with one pair of simple appendages.
6. Excretion by both antennal and maxillary glands.
7. Ventral nerve cord paired.
8. Sexes separate, earliest larva is metanauplius.

   Example: *Derocheilocarus.*

Subclass 4. Copepoda

1. Fresh water or marine, free-living, commensal or parasitic.
2. Body small, elongated, composed of head, thorax and abdomen,
3. Typically 10 free trunk somites, with 4 lacking appendages. Appendages mostly biramous.
4. Three ocelli often fused as median eye, no compound eyes.
5. Antennules and antennae well developed and used for swimming.
6. Abdomen without appendages, ends in a pair of caudal styles.
7. Excretion by maxillary gland.
8. Eggs on abdomen of female in 1 or 2 egg sacs.

Subclass Copepoda is divided into 7 orders.

Examples: *Cyclops, Salmincola, Caligus, Doropygus, Calanus, Monstrilla.*

Subclass 5. Branchiura

1. Ectoparasites of fresh water and marine fishes and some amphibians.
2. Body flat, carapace large, disk-like, covering head and thorax.
3. Abdomen small, bilobed.
4. First maxillae modified as suckers.
5. Compound eyes present, sessile.
6. Thoracic appendages 4 pairs, large, biramous, some of them are provided with flagella.

   Example: *Argulus.*

Subclass - 6. Cirripedia

1. Marine forms.
2. Adults sessile, attached or parasitic; attached by cement gland on first antenna.
3. Carapace becomes calcareous and mantle surrounding body.
4. Six or fewer pairs of slender and bristly biramous appendages behind mouth used in food gathering.
5. Abdomen vestigeal, without appendages, ending in a pair of caudal styles.
6. Antennae and compound eyes disappear in adult.
7. Monoecious. Development includes free swimming nauplius which passes through a cypris stage which is enclosed in bivalve shell.

The subclass is divided into following orders:

Order (i) Thoracica

1. Non-parastic sedentary marine barnacles.
2. Body surrounded by calcareous shell.
3. Six pairs of biramous thoracic limbs.
4. Alimentary canal is present.
5. Hermaphrodite.

   Examples: ***Balanus, Lepas.***

Order (ii) Acrothoracica

1. Parasitic, boring in the shells of mollusc.
2. Body is covered by large mantle. Calcareous shell is absent.
3. Less than 6 pairs of thoracic appendages.
4. Alimentary canal is present.
5. Chitinous disc is present for attachment.

   Example: ***Alcippe.***

Order (iii) Ascothoracica

1. Parasitizing corals and echinoderms.

2. Mouth appendages are modified into piercing and sucking organs.
3. Digestive tract with branches into mantle.
4. 6 pairs of trunk appendages.

   Examples: *Laura, Petrarca.*

Order (iv) Apoda

1. Parasitic in mantle cavity of Alepas.
2. Body without mantle and thoracic appendages.
3. Body maggot-like.
4. Anus absent.
5. Hermaphrodite.

   Example: *Proteolepas.*

Order (v) Rhizocephala

1. Parasitic on crabs.
2. A mantle but no shell.
3. Appendages, gut are absent.
4. Body sac-like, with absorptive roots penetrating host.

   Example: *Sacculina.*

Subclass-7-Malacostraca

1. Mostly large sized crustaceans, marine and fresh water.
2. Body typically of 19 segments (5 head, 8 thorax and 6 abdomen).
3. Exoskeleton of head united with few or more thoracic segments to form cephalothoracic carapace.
4. Stalked compound eyes.
5. Abdomanal caudal style absent.
6. Development through zoaea stage. Nauplius stage rarely occurs.

Series [A]. Phyllocardia.

1. Abdomen of eight somites.

Order (i) Leptostraca

1. Marine forms.
2. Body made up of 21 segments. Abdomen of 7 segments.
3. Thoracic appendages similar and foliaceous.
4. Telson has a pair of caudal styles.
5. Carapace bivaled. Eyes stalked.

   Example: *Nebalia.*

Series [B]. Eumalacostraca

1. Abdomen of 6 or fewer sometes.

SUPER ORDER [A] SYNCARIDA

1. Carapace is absent.

Order (i) Anaspidacea

1. Fresh waters of Australia.

   Example: *Anaspides.*

SUPER ORDER [B] PERACARDIDA

1. Carapace, when present, leaving 4 or more thoracic somites distinct.
2. Females with thoracic brood pouch where young develop.
3. Development direct without larval stage.

Order (i) Mysidacea

1. Marine forms.
2. Carapace covers almost entire thorax.
3. Eyes stalked.
4. Thoracic appendages are biramous.
5. Uropods form broad fan-like tail fin.

   Example: *Mysis.*

Order (ii) Cumacea

1. Small, mostly marine, burrowing in surface sand or mud.
2. Carapace with 2 anterior extensions often joined over head.
3. Head and thorax greatly enlarged.
4. Abdomen slender, mobile.
5. Uropods slender.

   Example: *Deastyles, Cumopsis.*

Order (iii) Tanaidacea

1. Minute, marine, upto depths of 3650 meters in mud or tubes.
2. Carapace is small and fused to first 2 thoracic segments.
3. Second thoracic appendage with chela.
4. Telson unjointed fused with last abdominal segment.
5. Uropods slender.

   Examples: *Tanais, Apseudes.*

Order (iv) Isopoda

1. Mostly marine, some freshwater and few parasitic.
2. Body usually depressed dorsoventrally.
3. Carapace is absent. Abdomen short, partly or all fused.
4. Gills and heart abdominal.

   Examples: *Ligia, Asellus, Hemioniscus, Oniscus.*

Order (v) Amphipoda

1. Mostly marine, some freshwater and terrestrial.
2. Body often laterally compressed.
3. Carapace is absent.
4. Telson usually distinct.
5. Gills and heart thoracic.

   Example: *Gammarus, Caprella, Cyamus.*

SUPER - ORDER [C] HOPLOCARIDA

1. Head with two movable anterior segment bearing eyes and antennules.

Order (i) Stomatopoda

1. Marine on bottom, in sand or cervices.
2. Antennae scale enlarged.
3. Gills on abdominal appendages modified for raptorial feeding.
4. Carapace small.

   Examples: *Squilla, Pseudosquilla, Chloridella.*

SUPER ORDER [D] EUCARDIA

1. Carapace is present, fused to and covering all the thorax.
2. Eyes stalked.
3. Gills thoracic.
4. Brood pouch absent.
5. Development usually indirect with a zoaea larva.

Ordr (i) Euphausiacea

1. Marine, small, pelagic forms.
2. Carapace does not cover sides of body and the gills.
3. Thoracic appendages all biramous and similar, none modified as maxillipeds.
4. Pleopods have long setae, used for swimming.
5. Larva is nauplius.

   Examples: *Euphausia, Thysanopoda.*

Order (ii) Decapoda

1. Mostly marine forms.
2. Carapace covers the entire thorax.
3. Thoracic appendages are modified as 5 pairs of walking legs and three pairs of maxillipedes.
4. Thoracic appendages mostly uniramous.
5. Statocyst present.
6. Gills usually present in three series on the thorax.

Decapoda is divided into 3 suborders:

Sub order (a) Macrura

1. Abdomen is well developed and elongated.
2. The abdomen terminates in an expanded fan-like tail fin composed of telson and the uropods.
3. Eyes are not enclosed in orbits.

   Examples: *Lucifer, Palaemon, Homarus, Astacus, Cambarus.*

Suborder (b) Anomura

1. Abdomen is more or less reduced and flexed.
2. Tail fin is also reduced.

   Examples: *Eupagurus, Hippa.*

Suborder (c) Brachyura

1. Abdomen greatly reduced, hard, permanently flexed under cephalothorax.
2. Antennules and the eyes are both capable of being retracted into cavities.
3. Rostrum and uropods absent.
4. First legs usually large and chelate.

   Examples: *Cancer, Inachus, Uca, Libinia, Inachus.*

CLASS - II MYRIPODA

1. Terrestrial and air breathing arthropods.
2. Body is usually elongated with numerous segments, each bearing one ~~or two~~ pairs of appendages.
3. Head is distinct, bearing a pair of antennae, mandibles, eyes and maxillae.
4. Respiration by tracheae.
5. Excretory organs are one or two pairs of Malpighian tubules associated with hindgut.
6. Sexes are separate.

Subclass-1 Progeneata

1. The genital apertures are situated near the anterior end of the body.

Order (i) Pauropoda

1. The trunk segments are eleven and anal segment is also present.
2. There are 9 pairs of legs.
3. The head bears one pair of antennae, one pair of mandibles and one pair of maxillae.
4. These are without blood vascular system and trachea.

   Example: *Pauropus.*

Order (ii) Diplopoda

1. Body is usually cylindrical.
2. Poison bears numerous segments each with two pairs of legs (expect first four).
3. Genital opening on the third segment behind the head.

   Example: *Julus, Millipede.*

Order (iii) Symphyla

1. There are not more than 12 segments in the trunk.
2. The head bears one pair of antennae, one pair of mandibles and 2 pairs of maxillae.
3. There is a single pair of tracheae.

   Example: *Scolopendrella, Scutigerella.*

Subclass - 2. Opisthogoneata

1. Genital apertures are situated at the posterior extremity of the body.

Order (i) Chilopoda

1. Body is usually dorsoventrally flatenned.
2. Head bears many jointed antennae, a pair of mandibles and two pairs of maxillae.
3. Poison jaws are present.
4. Trunk bears 15-117 segments each with a single pair of legs.

   Examples: *Scolopendra, Scutigers.*

CLASS III INSECTA

1. These are air breathing, mostly tarrestrial and rarely aquatic arthropods.
2. Body is divisible into head, thorax and abdomen.
3. Head bears a pair of antennae, compound eyes, mandibles and two pairs of maxillae.
4. Thorax consists of three segments bearing 3 pairs of legs and 2 pairs of wings.
5. Abdomen 7-11 segments which are without appendages in adult.
6. Liver absent but salivary glands are present.
7. Respiration by tracheae.
8. Excretion by Malpighian tubules.
9. Sexes separate.

10. Development is usually indirect, completed by complicated metamorphosis. Sometimes direct without larval stage.

Class Insecta is divided into two subclasses.

Subclass I Apterygota

Subclass II Ptergota.

Subclass - I - Apterygota.

1. Wingless, primitive insects.
2. Metamorphosis is absent.

Order (i) Protura

1. Minute, elongate, whitish insects.
2. Antennae, eyes and ocelli are lacking.
3. Wings are absent.
4. Abdomen short consists of 12 segments. Bilateral styli on first three segments.
5. Tracheae lacking.
6. Malpiglian tubules are small papillae.

   Example: *Acerentulus.*

Order (ii) Collembola

1. Minute, somewhat tubular or globose forms.
2. Eye patches consist of 1 to several lateral ocelli, dorsal ocelli lacking. Antennae short usually 4-segmented.
3. Abdomen consists of 6 segments, lobe-like organ on first segment. 4th segment bears furcula.
4. Mouth parts entognathus, chewing type.

   Examples: *Podura, Isotoma, Sminthurus.*

Order (iii) Archeognatha

1. Small, elongate, many with scales on part of body.
2. Mouth parts are ectognatous chewing type.
3. Antennae filiform, large compound eyes and 3 ocelli are present.
4. Abdomen small bilateral styli on venter of several segments.
5. Females with elongated jointed ovipositor.

   Example: *Machilis.*

Order (iv) Thysanura

1. Small, elongated insects. Usuelhy covered with scales.
2. Compound eyes usually present. O-3 ocelli.
3. Abdomen small, belateral style on venter of several segments.
4. Abdomen consists of 10 or 11 segments.

Examples: *Lepisma, Japyx.*

Subclass II Pterygota

1. Adults are winged, some are wing-less.
2. Metamorphosis complete or incomplete.

DIVISION (A) EXOPTERYGOTA (HETEROMETABOLA).

1. Wings develop externally as buds.
2. Metamorphosis simple without pupal stage.

Order (i) Odonata

1. Medium to very large sized insects.
2. Head large, mobile bearing short antennae, large compound eyes and 3 dorsal ocelli.
3. Two pairs of membraneous wings, venation net-like.
4. Abdomen elongate. Adult males with gonopores on 9th segment and complex penis on second segment.
5. Metamorphosis incomplete. The nymphs aquatic, predatory with caual tracheal gills.

Examples: Dragon flies (*Lestes*), Damsel flies.

Order (ii) Ephemeroptera

1. Soft bodied, fragile, small to medium sized.
2. Mouth parts chewing type in mymph and vestigial in adults.
3. Antennae short. Compound eyes and 3 ocelli are present.
4. Two pairs of membranous wings. Fore-wings larger than hind-wings.
5. Abdomen with a pair of long cerci and often with a median caudal filament.
6. Metamorphoses incomplete. Nymph bears gills of the first 4-7 segments.

Example: Mayflies (*Ephemera*).

Order (iii) Placoptera

1. Small to medium sized, soft-bodies, elongate, flatenned insects.
2. Mouth parts chewing type, usually vestigial in adults.
3. Antennae long and tapering. Well developed compound eyes, usually 3 dorsal ocelli are present.
4. Two pairs of membranous wings, males of some species apterous or brachypterous.
5. Metamorphosis incomplete. Nymphs aquatic with tracheal gills.

Examples: Stoneflies (*Isoperla, Pteronarcys*).

Order (iv) Embioptera

1. Minute to small, elongated insects.
2. Head large bearing filiform antennae, compound eyes present, ocelli absent.
3. Mouth parts chewing type.
4. Thorax nearly as long as abdomen.

5. Some males with 2 pairs of membranous wings of nearly equal size and shape. Females and some males wingless.
6. Metamorphosis gradual in male but absent in female.

   Example: Web-spinners (*Oligotoma*).

Order (v) Phasmida

1. Large sized insects. Body elongate, cylindrical with short prothorax, large meso- and meta-thorax.
2. Head broad and bears a pair of long filiform or moniliform antennae. Compound eyes are present. 2-3 or no ocelli.
3. Mouth parts biting type.
4. Wings present or absent.
5. Abdomen 11 segmented. Ovipositor small and somewhat concealed. Cerci short, unsegmented.

   Examples: *Phyllium, Carausius* (stick insect).

Order (vi) Orthoptera

1. Minute to very large sized insects.
2. Mouth parts chewing type. All gradation between hypognathous and opisthognathous.
3. A pair of antennae of variable structure.
4. Compound eyes and usually 2 or 3 ocelli are present.
5. Two pairs of wings are present. Forewings hard, narrow, parchment like opaque with indistinct venation forming tegmina (wing covers).
6. Abdomen 11 segmented. Females in several species with well developed ovipositors. Cerci variable, short, long, clasper-like, segmented or unsegmented.

   Examples: Grasshoppers (*Poecillocerus*), Locusts (*Schistocerca*), Crickets (*Gryllus*), Mole cricket (*Gryllotalpa*).

Order (v) Dermaptera

1. Small to medium sized insects.
2. Mouth parts chewing type.
3. Antennae long slender. Compound eyes present in most of the forms may be vestigial or absent in some forms.
4. Fore-wings short, leathery and veinless, hind-wings membraneous, broad, fan-like.
5. Abdomen 11 segmented bearing a pair of forceps-like cerci at the end.
6. Metamorphosis gradual.

   Example: Earwigs (*Forficula*).

Order (vii) Grylloblattoidea

1. Medium to large, some what elongate and slender.
2. Mouth-parts biting and chewing type.
3. Antennae filiform, compound eyes reduced or absent. Ocelli also absabt.
4. Wings absent.
5. Abdomen well developed with sword-shaped ovipositor. Cerci long.
6. Metamorphosis simple.

Example: *Grylloblatta.*

Order (viii) Isoptera

1. Social and polymorphic insects living in colonies under a caste system.
2. Mouth-parts chewing type.
3. Compound eyes are present in all ~~winged forme~~, present or absent in apterous forms. O or 2 dorsal ocelli are present.
4. Antennae short, moniliform or filiform.
5. Wings when present, two pairs, similar in size, shape and venation.
6. Cerci short and simple.
7. Metamorphosis simple.

   Examples: Termites (*Zootermopsis Nasutitermes*).

Order (ix) Blattaria

1. Medium to large sized insects, some what dorsoventrally flatenned.
2. Mouth parts chewing type.
3. Compound eyes well developed, 2 ocelli in some. Antennae long filiform.
4. Wings present or absent, when present forewings tegmina, hind wing membranous.
5. Pair of styli on 9th sternum of males. Ovipositor reduced and concealed by 7th abdominal sternum.
6. Metamorphosis simple.

   Example: *Periplaneta, Blattella.*

Order (x) Mantodea

1. Medium to large sized insects. Body usually elongate, somewhat cylindrical, with elongate prothorax.
2. Head small, triangular and bears large compound eyes with 3 or more ocelli.
3. Mouth parts chewing type.
4. Raptorial forelegs at anterior end of elongated prothorax.
5. Wings usually present in males, reduced or absent in females.
6. Abdomen comparatively short, multisegmented cerci, pair of styli usually associated with 9th sternum in males.
7. Metamorphosis simple.

   Example: Praying mantids (*Tenodera*).

Order (xi) Zoraptera

1. Minute sized insects.
2. Mouth parts chewing type.
3. Compound eyes and ocelli present in winged forms but absent in wingless forms.
4. Wings present or absent when present forewings larger than hindwings.
5. Abdomen short one segmented cerci.
6. Metamorphosis simple.

Example: *Zorotypus.*

Order (xii) Psocoptera

1. Minute sized insects. Head capsule large compared to rest of body.
2. Mouth parts chewing type. Labial silk-glands are present.
3. Compound eyes weakly or strongly developed. Ocelli 3 in winged forms absent in wingless forms.
4. Wings when present, two pairs, membranous.
5. Cerci absent.
6. Metamorphosis simple.

   Examples: Book-lice (*Liposcelis*), *Peripsocus.*

Order (xiii) Mallophaga

1. Small, apterous, ectoparasitic insects.
2. Body is broad or elongated, flatenned dorsally.
3. Head generally large. Compound eyes reduced. Ocelli absent.
4. Mouth parts biting type.
5. Cerci absent.
6. Metamorphosis absent.

   Examples: Chewing lice or biting lice (*Trichodectes, Menacanthus*).

Order (xiv) Anoplura

1. Minute, dorsoventrally flatenned, ectoparasitic.
2. Head narrower than thorax.
3. Mouth parts piercing and sucking, retracted into head when not feeding.
4. Compound eyes weakly developed or lacking, ocelli also absent.
5. Antennae short 3-5 segments, setiform.
6. Wings are absent.
7. Legs adapted for clinging to the hairs of the host and each terminating in a curved claw.
8. Metamorphosis absent.

   Examples: Human body - louse (*Pediculus*), *Phthirus.*

Order (xv) Thysanoptera

1. Minute to small sized insects, Body slender.
2. Mouth parts rasping and sucking type: Asymmetrical, the right mandible reduced or absent.
3. Small, compound eyes; 3 dorsal ocelli in winged forms absent in wingles forms.
4. Antennae short 6-10 segments.
5. Wings two pairs, narrow fringed; coupted by basel hooks.
6. Abdomen 10-11 segments with an ovipositor. Cerci lacking.

7. Metamorphosis simple.

   Example: Thrips (*Heliothrips*).

Order (xvi) Hemiptera

1. Medium to very large sized insects.
2. Mouth parts piercing and sucking type.
3. Antennae 2-10 or rarely 25 segmented.
4. Eyes large with or without ocelli.
5. Wings when present, two pairs, fore wings usually thickened basally and membranous apicalhy (suborder Heteroptera) and wholly membranous (suborder Hereroptera) and wholly membranous (suborder Homoptera).
6. A triangular plate is located between the bases of the wings.
7. Anal respiratory filaments are present in some aquatic forms and anal filaments in male coccids.
8. Metamorphosis gradual.

   Examples: Giant water bug (*Belostoma*), Bedbug (*Cimex*), Water strider (*Gerris*), Squash bug (*Anasa*), Leaf hopper (*Paraphlepsius*), Cicada (*Magicicada*).

DIVISION (B) ENDOPTERYGOTA (HOLOMETABOLA)

1. Wings develop internally.
2. Metamorphosis complete.

Order (i) Coleoptera

1. Minute to large sized insects.
2. Antennae variable in shape and size usually 11 segmented.
3. Compound eyes present or absent. Ocelli usually absent but present in some groups. Larva without compound eyes but lateral orelli present.
4. Forewings sclerotized elytra which protect the membranous hindwings at rest.
5. Legs typically cursorial, some adapted for swimming, jumping or digging.
6. Abdomen usually 10 segmented. Cerci absent.
7. Mouth parts biting and chewing types.
8. Larvae diverse usually catterpillar-like or maggot-like.
9. Metamorphosis complex.

   Examples: Ground beetle (*Calosoma*), Blister beetle (*Epicauta*), Alfalfa beetle (*Hypnera*).

Order (ii) Strepsiptera

1. Minute sized mostly endoparasitic insects.
2. Mouthparts with reduced mandibles.
3. Compound eyes present in males and free-living females.
4. Antennae flabellate in males, absent in females.
5. Wings two pairs in males, forewings clublike, hindwings membranous and fan-like.

6. 3-5 genital pores in the abdomen of females

   Example: *Stylops*.

Order (iii) Neuroptera

1. Small to very large-sized, soft-bodied insects.
2. Mouth parts chewing type in adult and grasping-sucking type in larvae.
3. Compound eyes present. Ocelli present or absent.
4. Antennae filiform.
5. Wings two pairs, similar in size and appearence.
6. Cerci absent. Variously modified ovipositors are present.
7. Metamorphosis complete.

   Examples: Green lacewing (*Chrysopa*), Snakefly (*Agulla*), Dobsonfly (*Corydalis*).

Order (iv) Mecoptera

1. Small to medium sized, slender, predaceous insects.
2. Head usually elongated. Mouth parts chewing type.
3. Compound eyes are present. Ocelli 0-3. Antennae long and filiform.
4. Wings 2 pairs, membranous, commonly with dark spots.
5. Cerci shorts, simple or two segmented.
6. Metamorphosis complete.

   Examples: Scorpionfly (*Panorpa*), Hanging scorpionfly (*Bittacus*).

Order (iv) Diptera

1. Minute to medium sized, diurnal, nocturnal, terrestrial or aquatic insects.
2. Mouth parts variously modified for sucking, lapping, piercing and sponging.
3. Compound eyes present. Most species with 3 ocelli.
4. Wings are present, fore wings developed for flight while hind wings are reduced to halters.
5. Cerci present or absent.
6. Metamorphosis complete.

   Examples: Mosquitoes (*Aedes, Anopheles, Culex*), Black fly (*Simulium*), House fly (*Musca*), Fruit fly (*Drosophila*).

Order (v) Siphonoptera

1. Minute, hard-bodied bilaterally compressed insects.
2. Mouth parts piercing and sucking type. In larvae chewing type.
3. Compound eyes lacking. Generally 2 ocelli.
4. Antennae short contained within antennae grooves.
5. Wings absent.
6. Male terminalia highly modified with one pair of 2 segmented claspers. Cerci lacking.

7. Metamorphosis complete.

   Examples: Human fleas (*Pulex*), Polutary flea (*Echinophaga*), Rat flea (*Xenopsylla*), Dog and cat flea (*Ctenocephalides*).

Order (vi) Trichoptera

1. Small to medium sized insects.
2. Monthparts are non-feeding in adult stage. Adapted for inbibing fluid. Mandibles weakly developed or lacking. Larval with chewing type.
3. Compound eyes present, O or 3 ocelli.
4. Antennae range from setaceous to filiform.
5. Wings 2 pairs, membranous, hind wings broader then forewings; covered with modified hair-like setae.
6. Larvae aquatic.
7. Cerci one or two segmented.
8. Metamorphosis holometabolic.

   Example: Caddis fly (*Philopotamus*).

Order (vii) Lepidoptera

1. Medium to large sized insects.
2. Body and wings are completely covered by flat over lapping scales and hairs.
3. Mouth parts usually long, sucking proboscis.
4. Large compound eyes; O or 2 dorsal ocelli.
5. Antennae always prominent, vary in form.
6. Wings two pairs, forewings often largest.
7. Metamorphosis complete.
8. Larvae called caterpillars with 3 pairs of thoracic legs and 2-4 pairs of abdominal prolegs.

   Examples: Butterflies (*Danaus*), Moths (*Bombyx*).

Order (viii) Hymenoptera

1. Minute to large sized, social or parasitic insects.
2. Antennae 12 segmented in male and 13 segmented in females.
3. Mouth parts variable, chewing to lapping or sucking.
4. Compound eyes usually well developed. Commonly three dorsal ocelli.
5. Wings two pairs of membranous. Hindwings smaller then forewings, many wingless.
6. Abdomen with basal pedical.
7. Female with conspicuous ovipositor modified into saw, drell or sting.
8. Metamorphosis complete.

   Examples: Honey bees (*Apis*), Thief ant (*Solenopsis*), Warp (*Vespa*), Ants etc.

CLASS IV ARACHNIDA

1. These are air breathing, mostly terrestrial arthropods.
2. Body is divisible into cephalothorax and abdomen.
3. Cephalothorax bears two pairs of jointed appendages the cheliceral and padipalpi and four pairs of legs.
4. Antennae and true jaws are absent.
5. Eyes are sessile and simple.
6. Respiration by tracheal or book lungs or book-gills.
7. Heart is dorsal and tubular.
8. Excretion by coxal glands or Malpighian tubules or both.
9. Sexes are separate with conspicuous sexual dimorphosim.
10. Development direct.

Order (i) Eurypterida

1. Extinct forms.
2. Exo-skeleton is characteristically sculptured.
3. Cephalothorax is relatively small and the abdomen bears 12 free segments and a telson.
4. Cephalothorax bears 6 pairs of appendages.

   Example: *Eurypterus*.

Order (ii) Xiphosura

1. Marine arachnids burrowing in the sand.
2. These animals have large subcircular, apparently unsegmented body with two body divisions - anterior large cephalothorac (prosoma) and posterior small abdomen (opisthosoma), the two - joined by a hinge.
3. The cephalothorax bears a pair of short chelate appendages and 5 pairs of legs.
4. Abdomen bears operculum.
5. Respiration takes place by lamelliform gills attached to the abdominal appendages.
6. Sexes separate. Development includes a trilobite larva.

   Example: King crab (*Limulus*).

Order (iii) Scorpionidea

1. Terrestrial animals found under stones in tropical and sub- tropical regions.
2. Body is divisible into cephalothorax and abdomen.
3. Prosoma bears a pair of chelicerae, a pair of pedipalpi and four pairs of walking legs.
4. Respiration takes place by 4 pairs of book - lungs.

   Examples: *Palamnaeus, Buthus.*

Order (iv) Pedipalpida

1. Body consists of cephalothorax and abdomen.

2. The chelicerae are simple and non-chelate.
3. Respiratory organs are two pairs of book lungs.

   Example: *Phryniclus.*

Order (v) Araneida

1. Found under stones, bark, leaves etc.
2. Body consists of an undivided cephalothorax and an unsegmented abdomen.
3. Cephalothorax bears 6 pairs of appendages.
4. Chelecerae are subchelate with poison glands. Pedipalpi are simple and 6 jointed.
5. Eight eyes are arranged dorsally on the head.
6. Respiration by book-lungs or book-lung with tracheae.

   Example: Spider (*Aranea*), *Argiope.*

Order (vi) Palpigradi

1. Small arachnids.
2. Body consists of cephalothorax and an abdomen of 10 segments.
3. Chelecerae are chelate and pedipalpi leg-like.
4. Respiratory organs are 3 pairs of book-lungs.

   Example: *Koenenia.*

Order - (vii) Solifugae

1. Body divisible into prosome and opisthosoma.
2. Prosome consists of three fused and last three free segments.
3. Opisthosoma composed of 10 segments is not marked off from prosoma.
4. Chelecerae are large and chelate. Pedipalpi are elongated and leglike.
5. Respiration by tracheae. Poison gland are absent.

   Example: *Goleodes.*

Order (viii) Pseudoscorpionidea

1. Minute arachnids having the appearance of scorpion, found under the tree barks.
2. Body consists of cephalothorax and an abdomen of 12 segments.
3. A pair of spinning glands are present.
4. Respiration by tracheae.

   Examples: *Chelifer.*

Order (ix) Ricinulei

1. Body consists of cephalothorax and an abdomen of 9 segments.
2. Cephalothorax and pedipalpi bears movable plates or cucullus.
3. Respiratory organs are tracheae.

Example: *Cryptocellus.*

Order (x) Phalangida

1. Body consists of unsegmented cephalothorax and an abdomen of 10 segments.
2. Chelecerae are chelate and pedipalpi leg - like.
3. Spinning glands are absent.
4. Respiratory organs are tracheae.

   Example: *Obligolophus.*

Order (xi) Acarina

1. Body is unsegmented.
2. Chelecerae and pedipalpi are usually small and associated with the mouth parts.
3. Mouth parts are piercing and sucking type.
4. Respiration by tracheae or skin.

   Example: Ticks (*Ixodes*), Mites (*Chorioptes*).

PHYLUM ONYCHOPHORA

1. Aberrant forms as its several characters are of phylum Annelida and Arthropoda combined.
2. Body-soft, worm-like covered by papillae and hairy spines.
3. Cuticle is free, having transverse rings, metamerism not marked externally.
4. Jaws are only one pair.
5. Series of shout, fleshy, legs pairs provided with two claws.
6. Respiratory organs are tracheae.
7. Sexes are separate.
8. Regarded as living fossil.

   Example: *Peripatus.*

BRANCHIPUS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Branchiopoda
Order	-	Arostraca
Genus	-	*Branchipus*

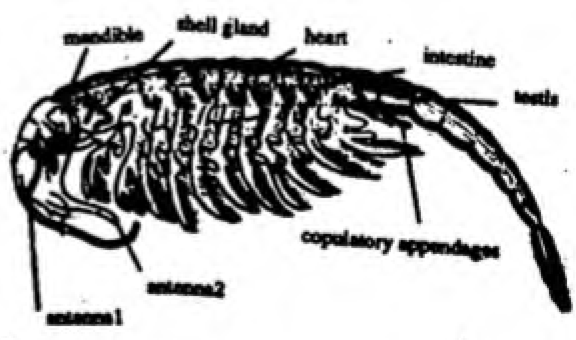


Fig. 46.1 *Branchipus.*

1. It lives in fresh water lakes, ponds etc.
2. It is commonly known as 'brine shrimp'.
3. Body is elongated pinkish, semitransparent and differentiated into head, thorax and abdomen.
4. Carapace is absent.
5. Eyes are situated on unjointed stalkes.

6. Antennae many and are modified into prehensile organs.
7. The cacedal styles are enjointed.
8. Eggs are laid in mud during summer and hatch in the next summer.

APUS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Brnachiopoda
Order	-	Notostraca
Genus	-	*Apus*

1. It is a fresh water crustacean found in most parts of the world especially in U.S.A., Kansas, Texas, Mexico etc.
2. It is commonly called 'tadpole shrimp'.
3. Body is elongated with broad shield-shaped carapace like horse shoe.
4. Head is broad and depressed bears paired eyes, a median eyes and a dorsal organ above the antennules and antenna below.
5. Shell glands are present on the lateral surface of carapace.
6. The original segments of the body seem replaced by secondary annulation.
7. Caudal styles are long, filamentous and jointed.
8. Males are rare, hence reproduction commonly occurs by parthenogenesis.

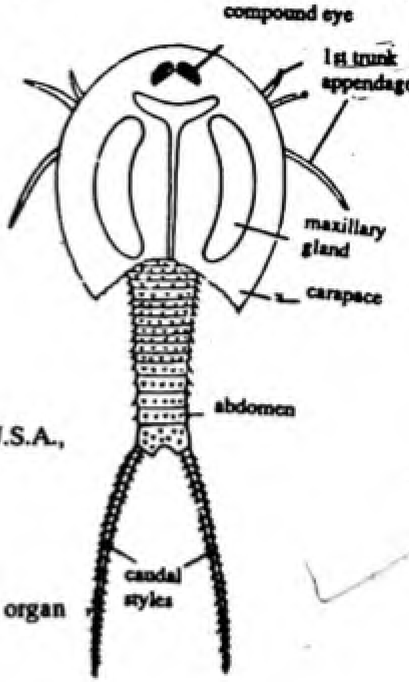


Fig. 46.2 *Apus.*

DAPHNIA

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Branchiopoda
Order	-	Cladocera
Genus	-	*Daphnia*

1. It is fresh water crustacean found in ponds, pools and ditches.
2. It is commonly known as 'water flea'.
3. The body except head is covered by folded carapace.
4. Head and abdomen are turned downward.
5. Head bears sessile eyes, nuchal sense organs above it, a pair of entennules, a pair of biramous antennae, large mandibles and two pairs of maxillae.
6. Large biramous antennae are the chief organ of locomotion.
7. Thorax bears usually five pairs of leaf like appendages.
8. Abdomen is devoid of appendages.
9. The female consists of a brood pouch between posterior part of carapace and abdomen in which eggs are stored.

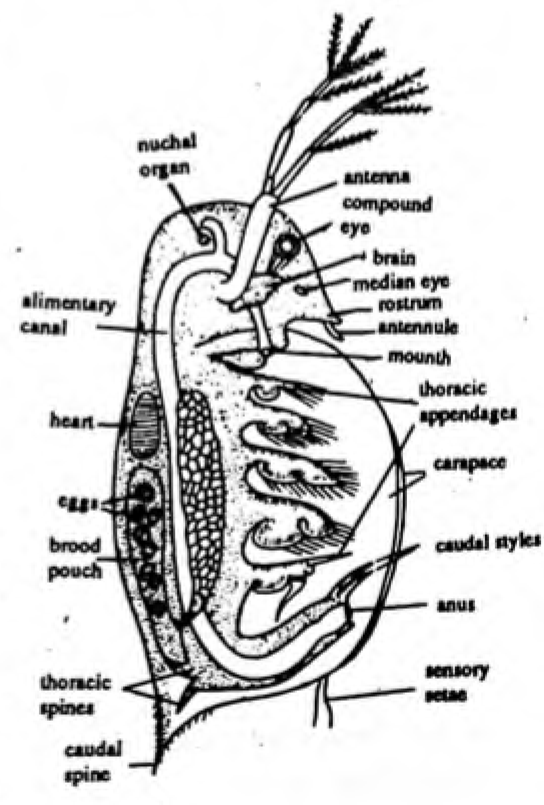


Fig. 46.3 *Daphnia.*

10. The alimentary canal is simple.
11. Heart is a little sac.
12. It is a delicious food for many aquatic animals.
13. Sexes are separate. Female carries eggs and embryos in a large brood pouch situated between abdomen and posterior part of the carapace.
14. No larval stage occurs.

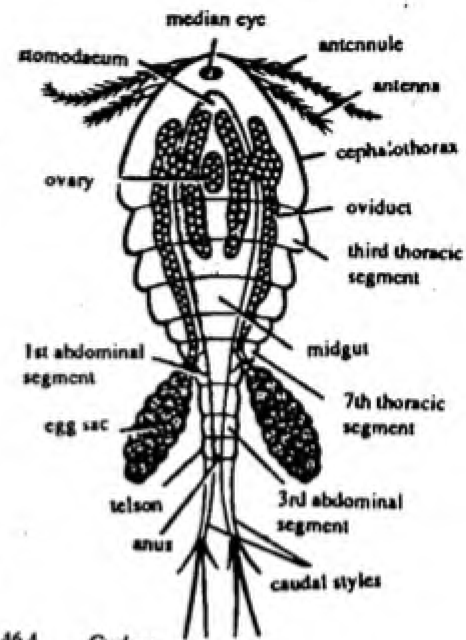


Fig. 46.4 *Cyclops.*

CYCLOPS

Phylum	-	Athropoda
Class	-	Crustacea
Subclass	-	Copepoda
Genus	-	*Cyclops*

1. *Cyclops* is found in fresh water ponds, ditches and also in brackish water.
2. The body is elongated, somewhat oval in shape.
3. The cephalothrax is formed by the fusion of head and the first thoracic segments.
4. Carapace is absent.
5. The cephalothorax is followed by the five free segments of the thorax and an abdomen of four segments.
6. The last segment of the thorax is fused in the female which first abdominal segment and bears the genital openings.
7. The antennules are large, entire and segmented and they are meant for copulation in male.
8. The antennae are short and the mandibles have palps.
9. There are two pairs of maxillae following with are maxillipedes and which are the first thoracic appendages. Rest are used for swimming.
10. Abdomen is devoid of appendages except the caudal styles.
11. Sexes are separate. Mature female carries two egg sacs attached to the abdomen.

CYPRIS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Ostracoda
Genus	-	*Cypris*

1. It is free-swimming and occurs in fresh water stagnant ponds.
2. It has about 2 mm long, unsegmented, laterally compressed, clam- like body enclosed in a bivalved shell. The vlves of the shell are closed by a transverse adductor muscle.
3. Compound eyes are absent but there is a prominant median eye. Antennule and antennae are large.
4. It is an omnivorous filter feeder.

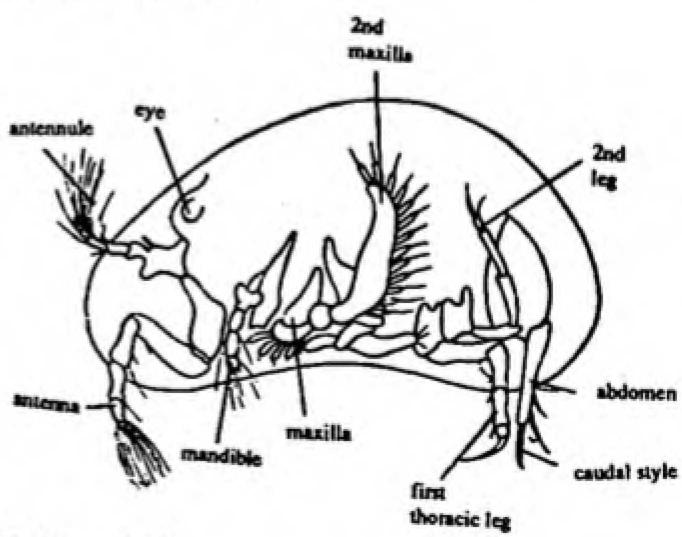


Fig. 46.5 *Cypris.*

5. **Abdomen is devoid of appendages and terminates into two caudal styles.**
6. **Respiration by integument.**
7. **Development by parthenogenesis.**

ARGULUS

Phylum	-	Arthopoda
Class	-	Crustacea
Subclass	-	Branchura
Genus	-	*Argulus*

1. It is an ectoparasite on fresh water fishes and usually found in the walls of branchial cavity.
2. It is commonly known as 'carp louse'.
3. Body consists of an oval flatenned cephalothorax and a small bilobed abdomen.
4. Mandibles and maxillae form piercing organs and are surrounded by a sucking tube called proboscis.

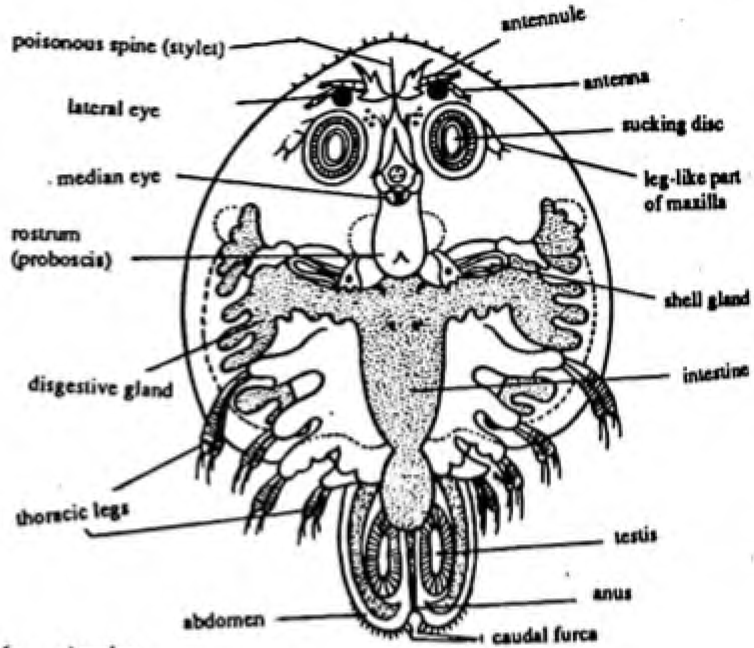


Fig. 46.6 *Argulus.*

5. A poisonous spine, the stylet, lies in front of the proboscis.
6. Second maxillae are divided into two parts, an anterior sucking disc for attachment and a posterior leg like part.
7. A pair of large compound eyes and a median eye are present on the head.
8. Thorax bears 4 pairs of swimming appendags.
9. Gills are absent, respiration probably through the carapace surface.

LUCIFER

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Decapoda
Genus	-	*Lucifer*

1. It is a pelagic crustacean found in India, Asia and Europe.
2. The animal is minute, delicate and slender.
3. Body is divisible into cephalothorax and abdomen.
4. Cephalothorax is smaller than abdomen.
5. Head is elongated and bears long antennae and stalked eyes.
6. The thoracic appendages are non-chelate and the last two thoracic somites are without appendages.

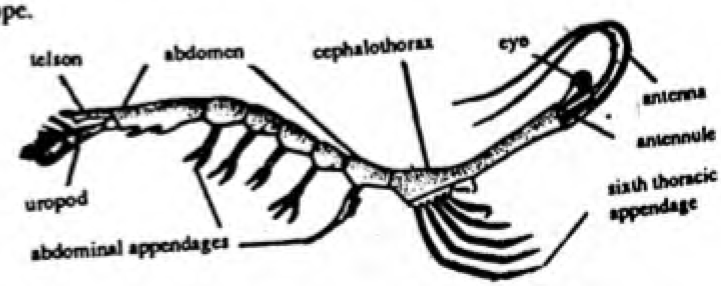


Fig. 46.7 *Lucifer.*

7. Gills are absent.
8. Development indirect through nauplius larva which moults through zoaea and a mysis stages.

MYSIS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Mysidacea
Genus	-	*Mysis*

1. It is found sometimes in sea water and some times in fresh water.
2. *Mysis* is a small transparent, shrimp-like form.
3. Body is bilaterally compressed and elongated measuring from 2-6mm in length.
4. Carapace covers the entire thorax except the last two segments.
5. Head bears antennules, antennae and a pair of stalked eyes.

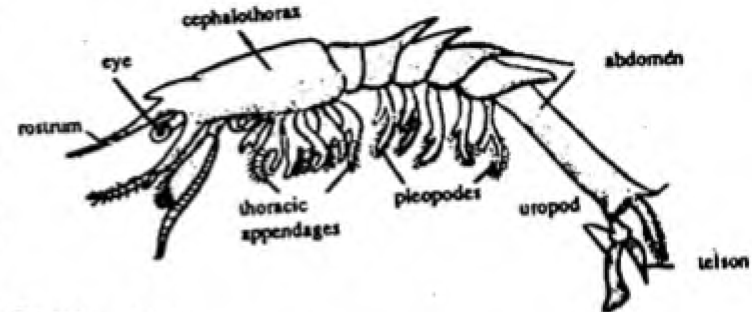


Fig. 46.8 *Mysis.*

6. First pair of thoracic appendages are modifies as maxillipedes and the rest are biramous serving as swimming organs.
7. Brood pouch is attached to the posterior thoracic segments.
8. Development takes place within the brood pouch, so there is no larval stage.

GAMMARUS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Amphipoda
Genus	-	*Gammarus*

1. It is marine as well as found in fresh water. It is commonly called 'sand-flea'.
2. Body elongated and laterally compressed.
3. Cephalothorax is formed by the fusion of head and first thoracic segment.
4. Carapace lacking.
5. Head bears a pair of antennule, antennae and sessile eyes.
6. First thoracic segment bears maxillipeds and the remaining seven segments bear walking legs. First two pairs of legs are chelate.
7. The abdomen is of a considerable size and flexed ventrally, bears a bifid telson.
8. First three pairs of abdominal appendages are used for swimming and rest for jumping on the ground.
9. It feeds on dead and decaying organisms.

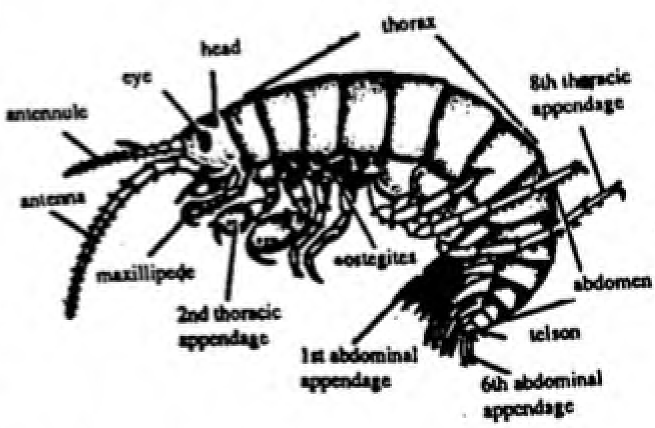


Fig. 46.9 *Grammarus.*

LEPAS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Cirripedia
Order	-	Thoracica
Genus	-	*Lepas*

1. It is sessile in habit and found attached in the clusters of floating objects like logs and the bottom of ships in the sea.
2. It has cosmopolitan distribution.
3. It is commonly called the 'goose barnacle'.
4. Body consists of a long stalk or pedicel and the body proper or capitulum.
5. Pedicle is covered by wrinkled skin.
6. The capitulum is enclosed in a bivalve carapace strengthened by 5 calcareous plates, 2 proximal scuta, 2 distal terga and a single dorsal carina.
7. The pedicle is really the highly modified anteriormost part of the head contains the vestige of the antennules, ovaries and the cement gland which provide the stickly secretion for attachment.
8. Antennae and paired eyes are absent.
9. Mouth is provided with a pair of mandibles and two pairs of maxillae.
10. Thorax bears 6 pairs of appendages.
11. Behind the appendages is a penis.
12. Abdomen is reduced to a process without any appendages.
13. It is bisexual, paired testes lie at the side of digestive tract and ovaries in the pedicle.
14. Development indirect through nauplius which moults into cypris stage which metamorphoses into adult.

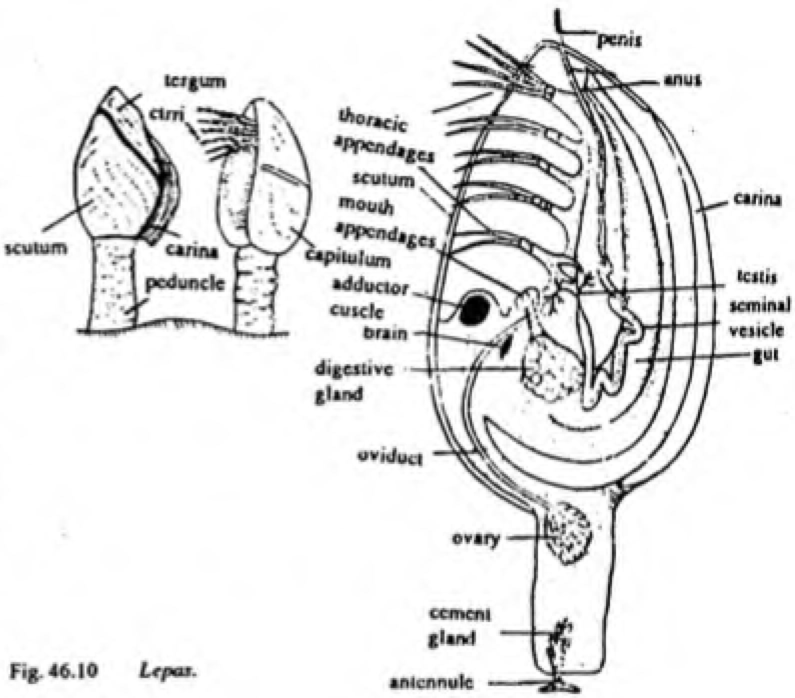


Fig. 46.10 *Lepas*.

BALANUS

The systematic position is the same as that the *Lepas*.

1. It is found attached to rocks and floating woods, shell of molluscs, carapace of turtle etc. in sea water.
2. It has cosmopolitan distribution.
3. It is commonly known as 'rock - barnacle' or 'acord - barnacle'.
4. It is sessible i.e. without pedicle, therefore, the body is directly attached to the rock or substratum.

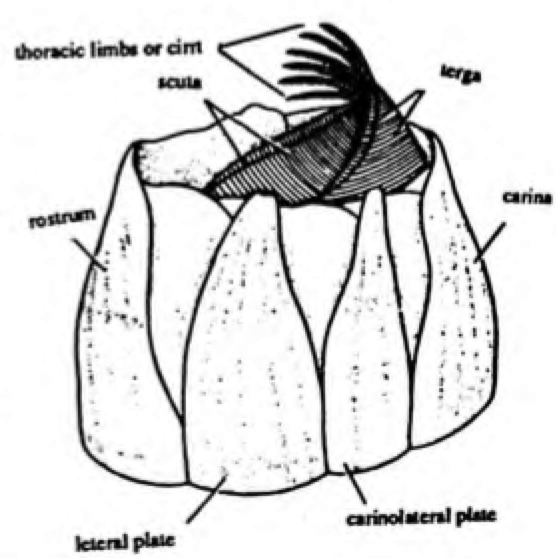


Fig. 46.11 *Balanus*.

5. Body is enclosed in a cylindrical case formed of six calcareous plates - unpaired carina and rostrum and two pairs of carino-laterals.
6. At the top of the shell there is an opening which is closed by two pairs of valves called opercular valves.
7. From the opening 6 pairs of thoracic feet which sweep in food particles of animal.
8. Eyes and antennae are absent.
9. Bisexual or hermaphrodite.
10. Development indirect and a nauplius larva is set free which moults into cypris stage and finally metamorphoses into adult.

SACCULINA

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Cirripedia
Order	-	Rhizocephala
Genus	-	*Sacculina*

1. *Sacculina* is parasite on carbs found attached between thorax and abdomen.
2. It has world wide distribution.
3. It is commonly called 'root-headed barnacle'.
4. Adult is extremely degenerate and appears as a fleshy tumour on the host.
5. Body without carapace, segmentation, appendages and alimentary canal.
6. The peduncle gives out many delicate root-like process into the tissue of host through which it absorbs nourishment.
7. Opening of mantle cavity at the posterior end of the body is known as cloacal aperture.
8. These are bisexual.
9. Development is indirect through cirripide nauplius, which transform into cypris. Cypris attaches itself to the crab by its antennules. The cypris moults and called kentrogen larva. It travels within the blood and attached to ventral side of intestine. Rootlets grow out from it and larva metamorphoses into adult.
10. It causes changes in the secondary sexual characters of host. Male crab develops female characters while female ovary degenerates. This is known as *Parasitic Castration.*

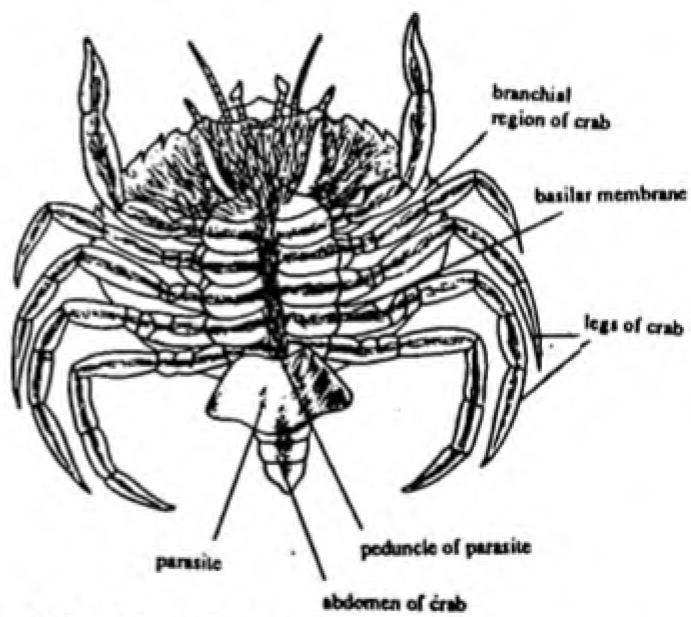


Fig. 46.12 *Sacculina* on the abdomen of crab.

ONISCUS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Isopoda
Genus	-	*Oniscus*

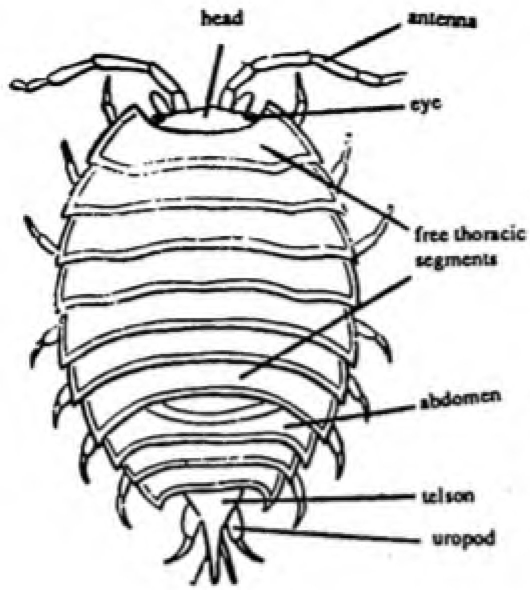


Fig. 46.13 *Oniscus.*

1. It is found under stones, woods, etc., in damp soil. It is found in Europe.
2. It is commonly called as 'wood lice'.
3. The body is oval and dorso-ventrally flatenned.
4. First thoracic segment fused with the head to form cephalothorax.
5. Unstalked compound eyes are present.
6. Antennules and antennae are uniramous.
7. The abdominal legs are adapted for aerial respiration and their endopodiates bear delicate branchiae traversed by minute tube called pseudotracheae.
8. Abdomen short.
9. Yongs develop in a brood pouch, present on ventral side.

SQUILLA

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Stomatopoda
Genus	-	*Squilla*

1. It is found in burrows of the sand or mud at the bottom of sea.
2. It is found in India, southern coast of Florida and Gulf of Mexico.
3. Body is elongated measuring 25 cm. in length, divisible into head, thorax and abdomen.

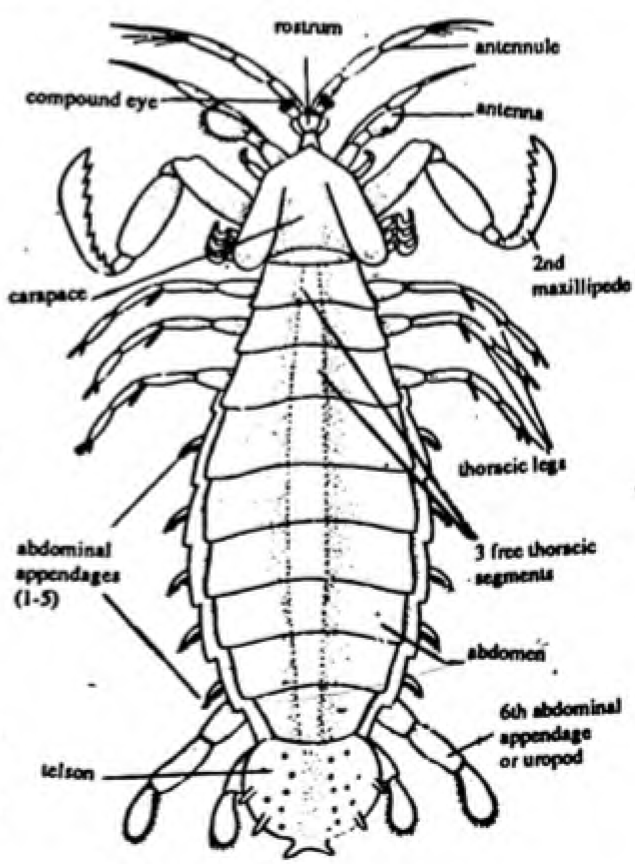


Fig. 46.14 *Squilla.*

4. Carapace is thin and uncalcified. It is produced anteriorly into a movable rostrum.
5. Compound eyes are stalked.
6. Anterior 5 pairs of thoracic appendages are uniramous and directed forwards to act as maxillipedes. The remaining thoracic appendages are biramous and act as legs.
7. The 2nd pair of maxillipedes are very large and form powerful prehensile weapons.
8. Abdomen is relatively large and has a broad telson bearing 3 pairs of marginal spines.
9. Pleopods are biramous and large. They bear gills on their exopodites.
10. Sixth form large uropods which are flaterred and form the tail- fan along with the telson.
11. The eggs are carried about by the last three pairs of maxillipedes.
12. The larvae are transparent pelagic alima, which metamorphoses into adult *Squilla*.

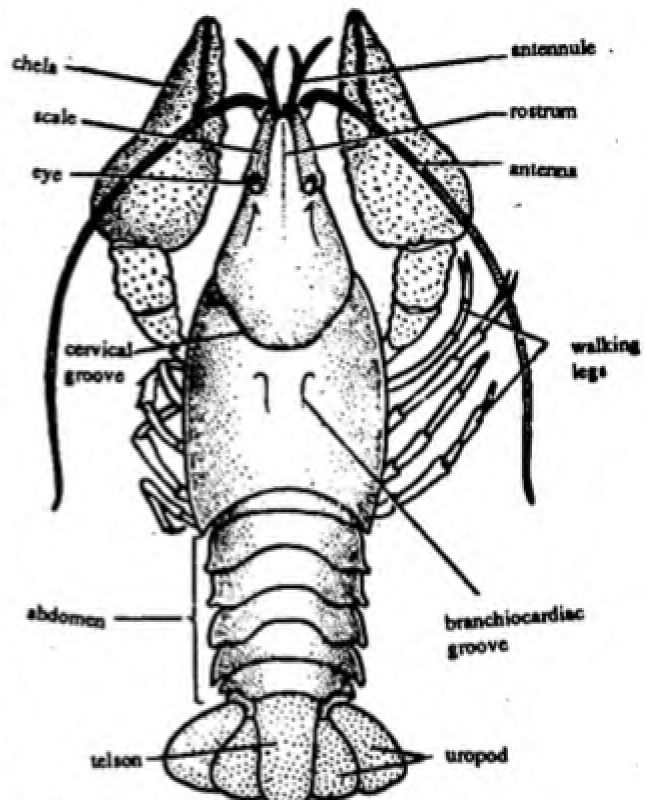


Fig. 46.15 *Astacus*.

ASTACUS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Decapoda
Genus	-	*Astacus*

1. *Astacus* is found in freshwater ponds, streams and lakes all over the world.
2. It is commonly called 'cray-fish'.
3. The body is long and robust, somewhat compressed.
4. Body is divisible into cephelothorax and abdomen.
5. The line of demarcation between the head and thorax is possibly indicated by cervical groove.
6. Rostrum is short and without serrated margins.
7. Head appendages 5 pairs. Eyes, antennules and antennae are present.
8. Thoracic appendages 8 pairs. First three pairs of thoracic legs are chelate and the first pair is largest.
9. Abdomen 6 segmented, with 6 pairs of appendages.
10. In females, eggs are carries on by the pleopods.
11. The development is direct.

EUPAGURUS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Decapoda

Genus *Eupagurus*

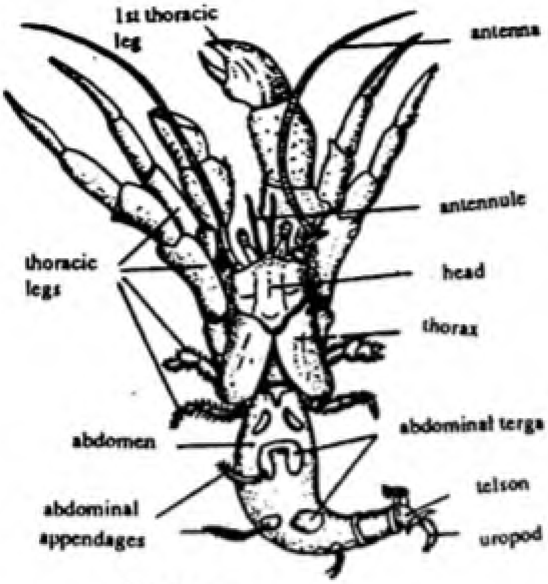


Fig. 46.16 *Eupagurus.*

1. It is found in the empty shells of gastropod molluscs.
2. It has cosmopolitan distribution.
3. It is commonly called 'hermit crab'.
4. The body is highly asymmetrical and consists of cephalothorax and abdomen.
5. Cephelothorax is broad and flatenned bearings short antennules, antennae and stalkes eyes.
6. Of the 5 pairs of thoracic legs, first are chelate, 2nd and 3rd are nonchelate, 4th and 5th are chelate but reduced.
7. Abdomen is soft, cylindrical, coiled and unsegmented. It bears reduced appendages on the left side and none on right side, Uropods are, however, well developed.
8. Swimmerets are found only in females for carrying eggs.
9. They show commensalism. The close association between the hermit crabs and sea-anemone in which both are benefetted by each other.

HIPPA

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Decapoda
Genus	-	*Hippa*

1. It is found in the sand near the sea. It is commonly found on Pacific Coast, U.S.A. and Oregon to Mexico.

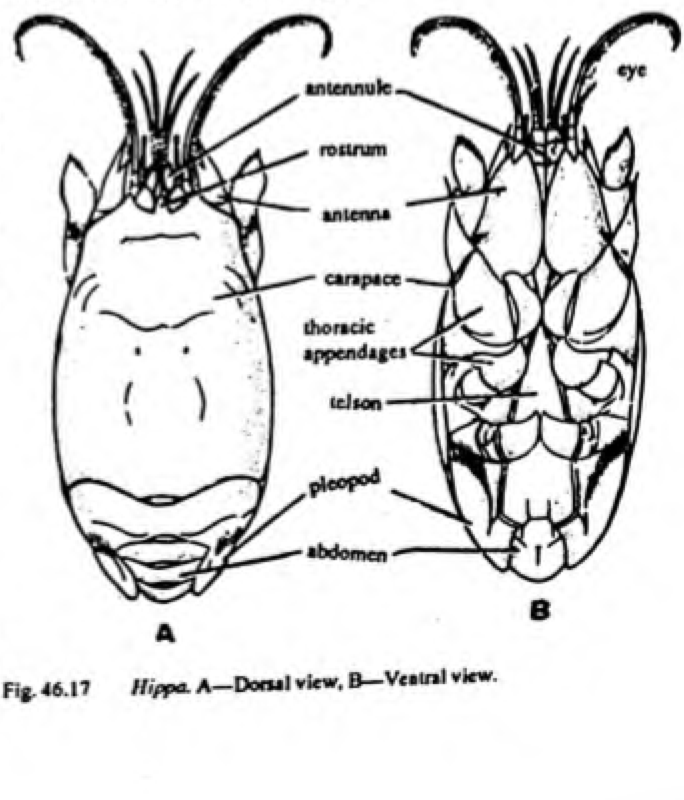


Fig. 46.17 *Hippa.* A—Dorsal view, B—Ventral view.

2. It is commonly known as 'mole-crab'.
3. Body is ovate with large cephatothotrax.
4. Carapace is smooth.
5. Mouthparts are poorly developed.
6. Head bears long stalked eyes, a pair of biramous antennules and a pair of uniramous antennae.
7. Rostrum is simple and pointed.
8. Thoracic appendages 7 pairs, walking legs 5 pairs adapted for digging. First two pairs of walking legs partially chelate.
9. Abdomen 6 segmented first three pairs of abdominal appendages modifies for swimming and last three pairs are adapted for darting.
10. Feeds like an earthworm, swallowing sand.

CARCINUS

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Decapoda
Genus	-	*Carcinus*

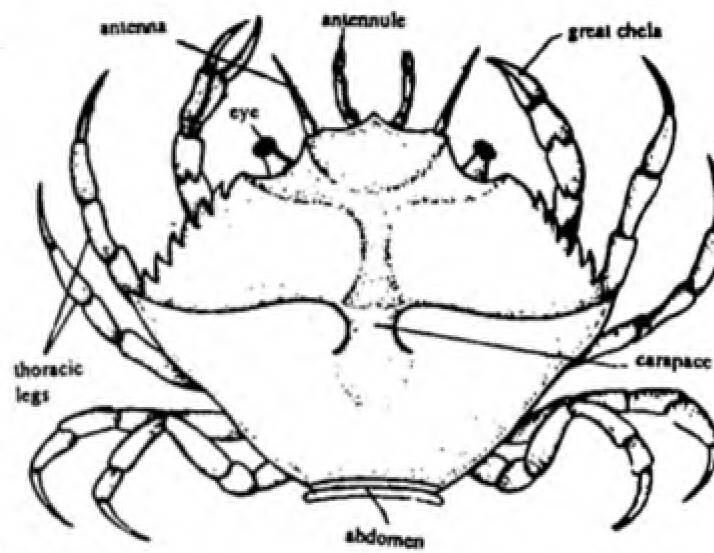


Fig. 46.18 *Carcinus.*

1. It is commonly found buried among rocks and in sand near about the water. It has cosmopolitan distribution.
2. Cephelophorax broad and somewhat oval with a broad carapace.
3. The antennae and antennules are short.
4. The eyes are stalkes and lodged in a pit of the cerapace.
5. Third maxillipedes broad, flat and plate - like.
6. Walking legs 5 pairs, the first pair is large chelate.
7. Abdomen reduced and is permanently flexed below cephalothorax.
8. Males with 2 pairs of pleopods, whereas female possesses 4 pairs of them. Uropods absent.
9. Eggs are carries by the females which are attached to the pleopods.
10. Development indirect. Egg develop into zoaea which passes into megalopa and finally metamorphoses into adult.

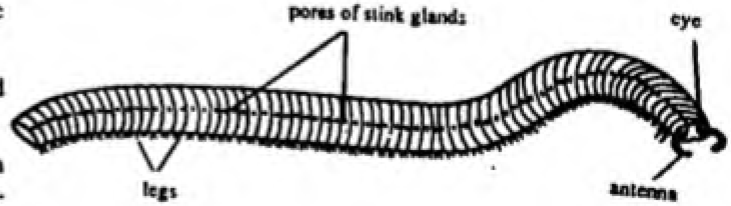


Fig. 46.19 *Julus.*

JULUS

Phylum	-	Arthropoda
Class	-	Myripoda
Subclass	-	Progoneata

Order	-	Diplopoda
Genus	-	*Julus*

1. It is found is damp and dark places under stones and decying leaves. When disturbed usually roll up into tight coil and emits an unpleasing odour from segmental scent glands.
2. It has cosmopolitan distribution.
3. It is commonly called as 'wire worm'.
4. Body cylindrical and metamerically segmented; differentiated into head and trunk.
5. Head small; antennae short generally 7 segment. One pair of maxillae and mandibles forming gnathochilarium.
6. Eyes are minute.
7. Trunk cylindrical consisting of very closely ring like segments from 25 to more than 100 segments.
8. In each segment there are two pairs of legs. Since it has numerous legs it is called millipede.
9. Poison glands and poison claws absent.
10. Vascular system well developed.
11. Respiration by tracheae.
12. Sexes are separate.
13. Genital openings situated at the anterior end of body.
14. In male one or both pairs of legs of 7th segment are modified to form copulatory organs.
15. Herbivorous and even scavanger.

SCOLOPENDRA

Phylum	-	Arthropoda
Class	-	Myripoda
Subclass	-	Opisthogoneata
Genus	-	*Scolopendra*

1. It is found under stones, in cervices and other dark places. It is found in India and America.
2. It is commonly called 'Centipede'.
3. Body is elongated and dorsoventrally flatenned with numerous segments.
4. Head is distinct and bears a pair of antennae, a pair of mandibles and two pairs of maxillae.
5. Trunk segments numerous, each bearing a single pair of legs.
6. First pair of trunk appendages or maxillipedes bears a sharp claw connected with the poison gland.
7. The last pair of legs are usually longer than the rest.
8. The anus lies at the posterior end.
9. Respiration is affected by tracheal tube.
10. The vascular system well developed.
11. Sexes are separate.

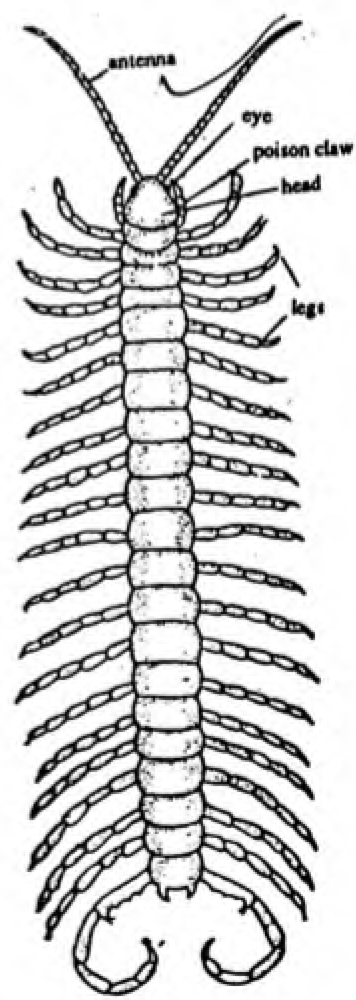


Fig. 46.20 *Scolopendra*. The centipede.

12. The genital opening situated at the hind end of the body.
13. Bite is dangerous to man and sometime proves to be fatal.

LEPISMA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Apterygota
Order	-	Thysanura
Genus	-	*Lepisma*

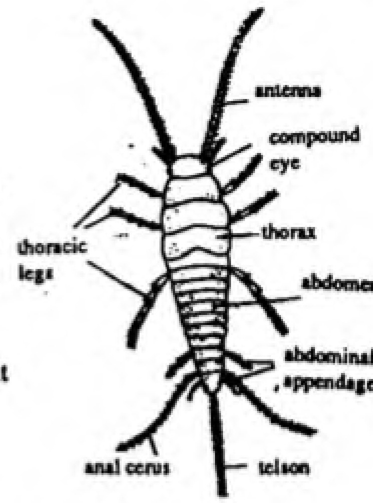


Fig. 46.21 *Lepsima*

1. It is found in houses, in books, papers, clothes, under pictures, in warm countries. It feeds on starch.
2. It is commonly known as 'silver fish'.
3. Body is flattered and covered with silvery, scales.
4. Body divisible into head, thorax and abdomen.
5. Head small with a pair of filiform antennae and eyes.
6. Mouth parts chewing type.
7. Thorax three segmented and bears 3 pairs of legs, wings are absent.
8. Abdomen 11 segmented with 3 anal cerci and a number of small delicate appendages.
9. Development direct without metamorphosis.

ISOTOMA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Apterygota
Order	-	Collembola
Genus	-	*Isotoma*

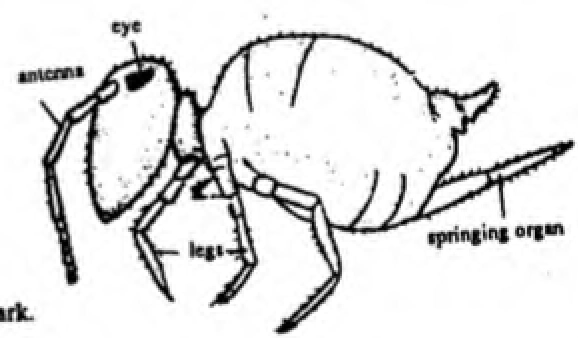


Fig. 46.22 *Isotoma.*

1. There are found in damp places, under leaves, cerives of bark.
2. It is commonly called 'Spring tail'.
3. Body is divisible into head, thorax and abdomen.
4. Head with 4 jointed antennae.
5. Compound eyes are absent, ocelli scattered.
6. Thorax 3 segmented with 3 pairs of legs. Wings absent.
7. Abdomen 6 segmented. First segment with a tubular adhesive organs, collophore. 3rd segment with tentaculum and 4th with furcula (spring organ).
8. It secrets glue-like substance used for sticking body to the object.

SCHISTOCERCA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota

Division	-	Exopterygota
Order	-	Orthoptera
Genus	-	*Schistocerca*
Species	-	*Gregaria*

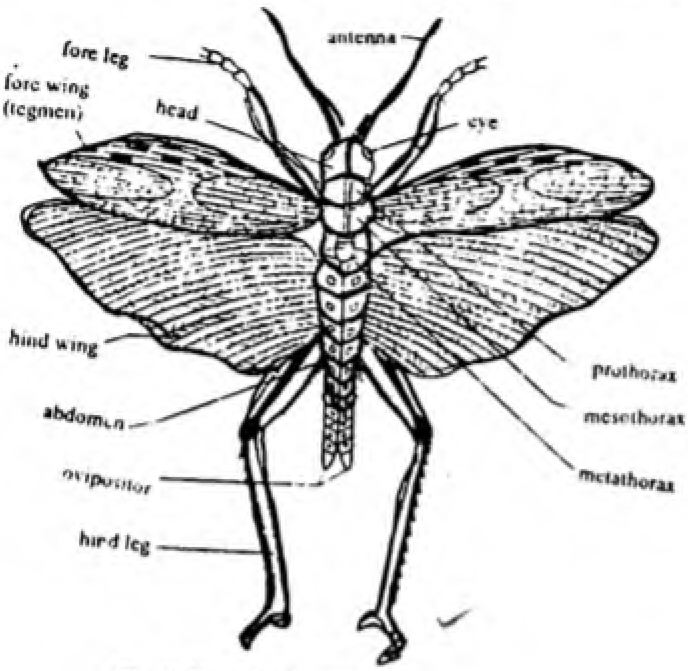


Fig. 46.23 *Schistocerca.*

1. Gregarious herbivorous insect found in green vegetation.
2. Commonly found in Africa, Arabia, India, Japan, Mexico, U.S.A. and Afganisthan.
3. Body is divisible into head, thorax and abdomen.
4. Head with a pair of long antennae and well developed compound eyes.
5. Thorax 3 segmented. 3 pairs of legs and two pairs of wings are present. Wings are dissimilar and unequal.
6. The fore-wing elongated, straight, thick, leathery with numerous brownish black spots.
7. The membranous hind-wing large, plaited anal area.
8. Legs well developed.
9. The hind legs modifies for jumping having long basally stout femora.
10. The abdomen has 10 evident and vestigial eleventh segment.
11. Mouth parts biting and chewing type.
12. Male with genital lamina incised posteriorly.
13. This is the most destructive of all locusts and its ravages were known in biblical times.
14. They occur in two phases: (a) *Solitary or non-migratory phase having yellow colour with dark green and brown pathces* (b) *Gregareous or migratory phase* have pink body with dark brown spots.

GRYLLUS

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Orthoptera
Genus	-	*Gryllus*

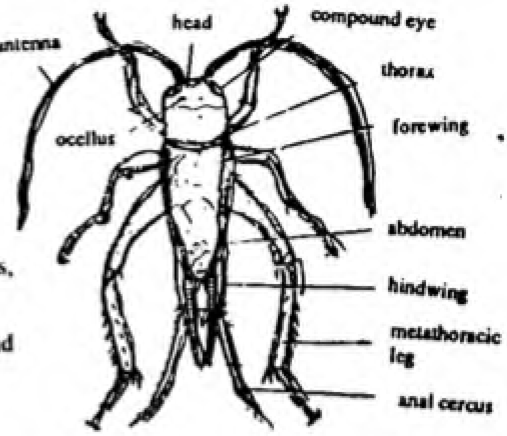


Fig. 46 24 *Gryllus.*

1. It is a noctural and omnivorous insect found under various objects, stones etc. during day time.
2. It is found in India, Sri Lanka, Asia, Burma, U.S.A., Europe and Canada.
3. It is commonly known as 'cricket'.
4. Body divisible into head, thorax and abdomen.
5. Head bears compound eyes and a pair of filiform antennae.
6. Mouthparts chewing type.
7. Forewings hard, narrow and parchment like with pigmented spots (tegmina). Hindwings are membranous and folded.
8. Tibia of the fore-legs bear tympanic organs and the hind-legs are modified for jumping.
9. Well developed ovipositor in females.
10. Male cricket chirps by rubbing front wings together during courtship.

GRYLLOTALPA

The systematic position is same as that of *Gryllus.*

1. *Gryllotalpa* is a nocturnal, burrowing insect.
2. It is found in Indian plains, warmer parts of Europe and Asia.
3. It is commonly known as 'mole cricket'.
4. Body is covered with short, fine hairs and is divisible into head, thorax and abdomen.
5. Head is well developed, bears a pair of antennae and compound eyes.
6. Mouth parts are biting and chewing type.
7. Tibiae of the first pairs of legs are expecially modifies with stout spines for digging purpose.
8. Forewings are short and hard membranous.
9. Ovipositor is not protruded.
10. Cerci are unjointed and long.

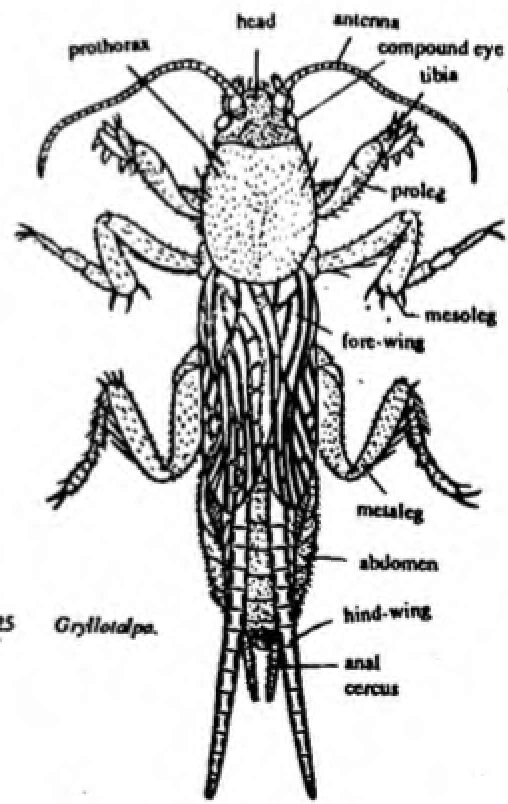


Fig. 46.25 *Gryllotalpa.*

MANTIS

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Mantodea
Genus	-	*Mantis*

1. These are arboreal feeding on living prey (carnivorous).
2. It is found in North America, U.S.A., Africa, South Europe, Western Asia.
3. It is commonly known as 'preying mantis'.
4. Body is long, slender, usually green in colour.
5. Body is divisible into head, thorax and abdomen.
6. Head is small, triangular with vertical face and freely movable on slender neck.

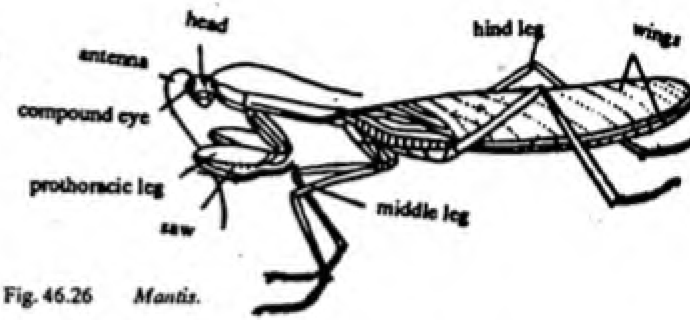


Fig. 46.26 *Mantis.*

7. Large compound eyes, three ocelli and long filiform antennae are present on head.
8. Mouthparts are chewing type.
9. Prothorax is much elongated and prothoracic legs are modifies for grasping and holding them prey.
10. Wings are well developed. These are folded flat and overlapping the sides of the body.
11. Abdomen 10 segmented. Ovipositor is no exected.
12. Nineth segment in males bear a pair of styli.
13. Short flattered and segmental cerci present.
14. Female eats the male after nuptial. 200 or more eggs are enclosed in the ootheca formed of frothy quick drying material.

PHYLLIUM

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Phasmida
Genus	-	*Phyllium*

Fig. 46.27 *Phyllium.*

1. It is found on the moist part of Oriental region, Forests of Assam etc.
2. It is commonly called 'leaf-insect'.
3. Body is broad and flatenned.
4. Body is divisible into head, thorax and abdomen.
5. Head is small bears small antennae.
6. Thorax is also small and bears 3-pairs of green coloured legs.
7. Tegmen or first pairs of wings are small than the other pair, having leaf-like colouration and veination.

8. Sexes distinct. Male with small tegmina, well developed wings and narrow bodies. Female with extensive tegmina produced into leaf like expansions.
9. It is an example of mimicry or camouflage in which protective resemblance in both form and colouration, is similar to the objects in their surroundings.

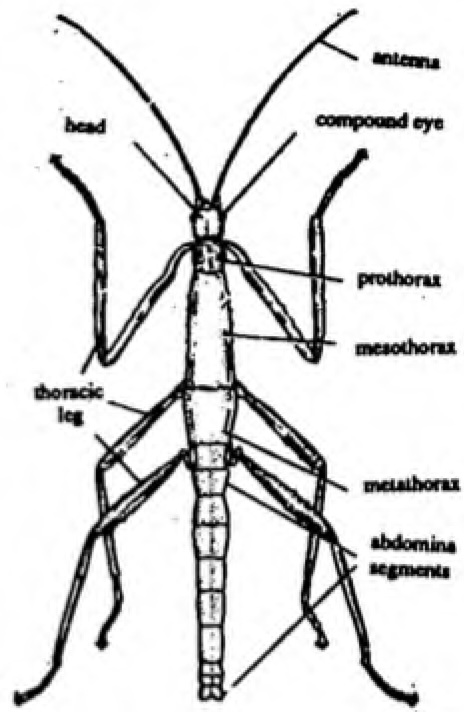


Fig. 46.28 *Carausius.*

CARAUSIUS

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Phasmida
Genus	-	*Carausius*

1. It is found in tropical forests and is arboreal, it is found in India, Sri Lanka, Burma, Asia, Europe.
2. It is commonly known as 'stick-insect'.
3. Body is elongated and slender with long legs and antennae resembling a twing or stick or any other foliage on which they feed.
4. Head is small with a pair of filiform antennae and compound eyes. Mounthparts chewing type.
5. Thorax is elongated bearing 3 pairs of legs and the wings are absent.
6. Abdomen 10 segmented.
7. Cerci small and unsegmented.
8. Sexes are separate, Male is small, active and winged. Female is large, sluggish and apterous.
9. Exclusively parthenogenesis.
10. Power of regeneration or autotomy is very great.

FORFICULA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Dermaptera
Genus	-	*Forficula*

1. Found under stones, moist places under stones in decaying vegetable matter etc.
2. It is found in Europe, N. America, Mexico, Asia, Africa and on the coasts of Indian ocean.
3. It is commonly known as 'earwing'.
4. Small insect with elongate body.
5. Body is divisible into head, thorax and abdomen.
6. Head contains a pair of eyes and a pair of long-filiform antennae.
7. Mouth parts chewing type.

Fig. 46.29 *Forficula.*

8. Thorax contains 3 pairs of walking legs and peculiar hindwings.
9. The forewings form hard veinless truncated wing cover below which the hindwings are present.
10. Anal cerci are modified into a pair of forceps which is raised upwards and is opened widely in a threatening manner, when the animal is disturbed.
11. Ovipositor absent.
12. Metamorphosis gradual and it exhibits parental care for eggs and young ones.

PEDICULUS

Phylum	-	Arthropoda
Class	-	Insecta
Suborder	-	Pterygota
Division	-	Exopterygota
Order	-	Anoplura
Genus	-	*Pediculus*

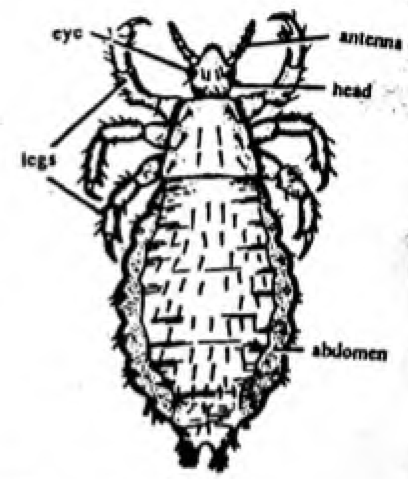


Fig. 46.30 *Pediculus.*

1. These are minute, flat, wingless and ectoparasite of man. It has cosmopolitan distribution.
2. It is commonly known as 'human louse'.
3. Body is dorso-ventrally flattered and pale in colour with dark marking along the sides.
4. Head bears a pairs of antennae which is 5 segmented, and a pair of compound eyes.
5. Mouthparts piercing and sucking type.
6. Thoracic segments are fused in one mass and contain 3 pairs of clawed legs, which form clinging organs with the tissue of the host.
7. Abdomen is 9 segmented.
8. Males are smaller than females and their posterior ends turned upward.
9. Metamorphosis is absent.
10. It is a major factor in transmitting relapsing fever, typhus and trench fever. It sucks the blood of man.

EPHEMERA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Ephemerida
Genus	-	*Ephemera*

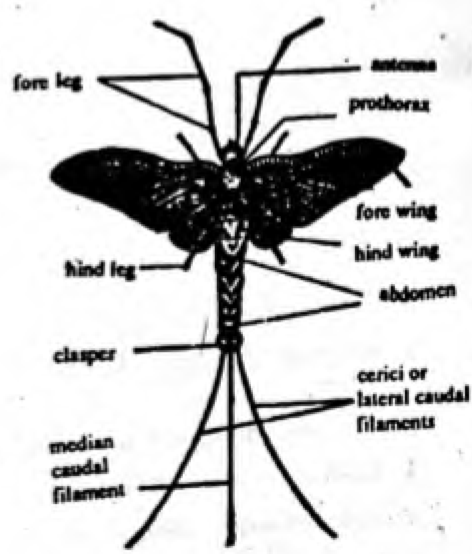


Fig. 46.31 *Ephemera.*

1. It is a soft-bodies and most familiar insect found on the margins of streams, lacks etc.
2. It is found in U.S.A., India, Sri Lanka and Burma.
3. It is commonly called as 'Mayfly'.
4. Body is divisible into head, thorax and abdomen.

5. Head is small contain small setose antennae, compound eyes and 3 ocelli.
6. Mouthparts vestigial.
7. 3 pairs of inconstant walking legs.
8. Two pairs of membranous wings, forewings larger than hindwings.
9. Abdomen is 10 segmented with a reduced tergum. Last segment bears a pair of long many jointed cerci. Tergum is produced into a long caudal filament.
10. Males has 3 jointed, clasping organ and the female has no ovipositor.
11. Nymph or naiad lives for a long time upto 3 years in water, feeding in aquatic plants and animals. The imago moults prior to mating and is extremely short lived.

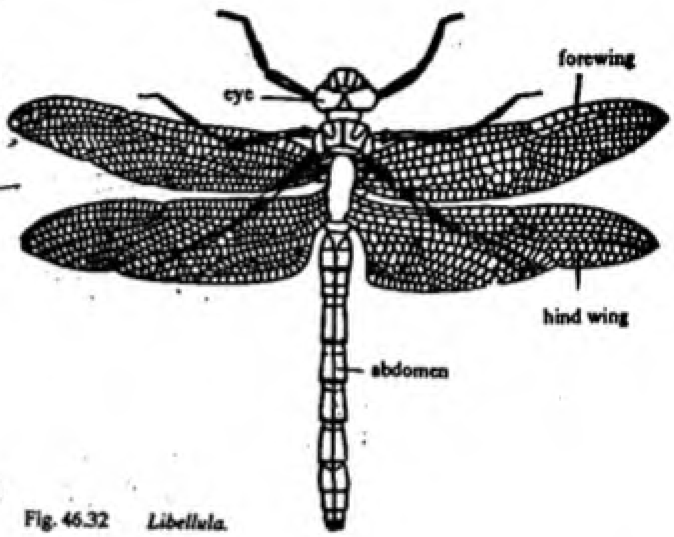


Fig. 46.32 *Libellula.*

DRAGON FLY

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Odonata
Genus	-	*Libellula*

1. It is of world wide distribution and generally found darting balancing in the air.
2. Body is slender and divisible into head, thorax and abdomen.
3. Head bears a pair of large compound eyes and small inconspicuous antenne.
4. Mouth parts chewing type.
5. Prothorax is small. Meso- and metathorax are fused. Legs are weak and used for resting.
6. Both pairs of wings are well developed and membranous. These are held in a horizontal position.
7. The abdomen in elongated often slender made up of 10 segments. The genital openings in both, male and female, lies at the hind end. Male copulatory organs on the 2nd and 3rd sternite.
8. Nymphs are aquatic, breath by rectal gills and feeding upon aquatic insects and organisms.

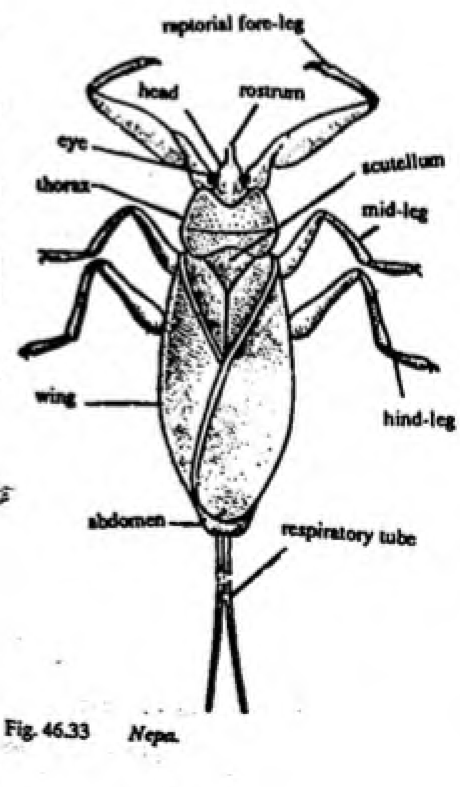


Fig. 46.33 *Nepa.*

NEPA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Hemiptera
Genus	-	*Nepa*

1. It is commonly found in shallow water. It has world wide distribution.

2. It is commonly called 'water scorpion'.
3. The body is dorsoventrally flatenned and divisible into head, thorax and abdomen.
4. Head comprises a pair of 3 jointed antennae and compound eyes.
5. Mouth parts form a long rostrum adapted for piercing and sucking.
6. The respiratory tube is most peculiar. It consists of two spine- like process.
7. There are three pairs of false spiracles situated on 3rd, 4th and 5th ventral abdominal segments respectively.
8. The false spiracles comprise sieve-like structures with the perforations occuleded by a delicate membrane.
9. Sexes are separate.
10. The female is provided with a pointed toothed ovipositor.
11. The eggs are deposited in chains. The ova adhere to one another by means of sevan long filaments radiating from one extremity.

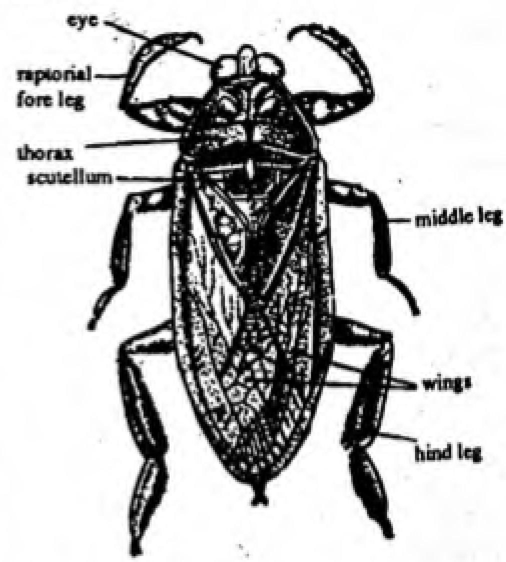


Fig. 46.34 *Belostoma.*

BELOSTOMA

The systematic position is the same as that of *Nepa.*

1. *Belostoma* is the largest insect found in rivers, ponds, lake, feeding on insects, tadpoles, snails etc.
2. It is found in India, U.K., North America and South Africa.
3. It is commonly called 'gaint water bug'.
4. Body is dorsoventrally flatenned and divisible into three parts, head, thorax and abdomen.
5. Head is small with a pair of large eyes and 4 jointed antennae. Mouth parts piercing and sucking type.
6. The thorax bears 3 pairs of legs. The midlegs and hindlegs are flatenned and adapted for swimming the forelegs raptorial.
7. First pair of wings hemielytra and second pair membranous.
8. The abdomen is provided with two retractile apical appendages.
9. Ovipositor well developed. Females of some species deposit their eggs on the back of male (parental care).

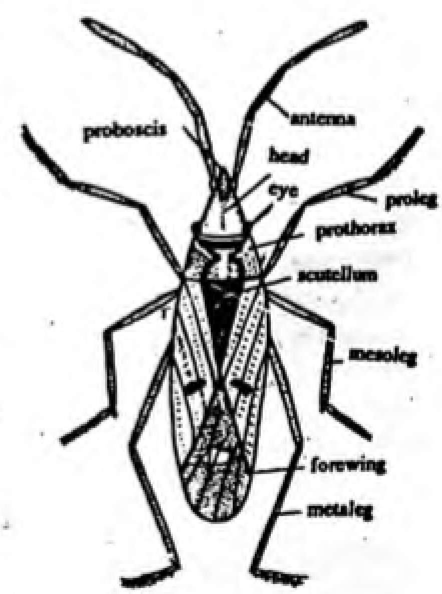


Fig. 46.35 *Dysdercus.*

DYSDERCUS

The systematic position is the same as that of *Nepa.*

1. It is a common pest of cotton and commonly known as 'Red cotton- bug'.
2. Body is black and red in colour.
3. Body divisible into head thorax and abdomen.
4. Head bears a pair of compound eyes and 4 jointed antennae.
5. Mouth parts piercing and sucking type.
6. Wings two pairs, basal half of the forewings hard and leathery (hemelytra), hindwings soft and membranous.

7. Triangular scutellum present between the bases of wings.
8. Pronotum large.

CICADA

The systematic position is same as that of *Nepa*.

1. It is found in the forests and moist places, abundant in tropical, subtropical and temperate regions.
2. Body is divisible into head, thorax and abdomen.
3. The head is broad possessing two lateral compound eyes and two very short antennae.

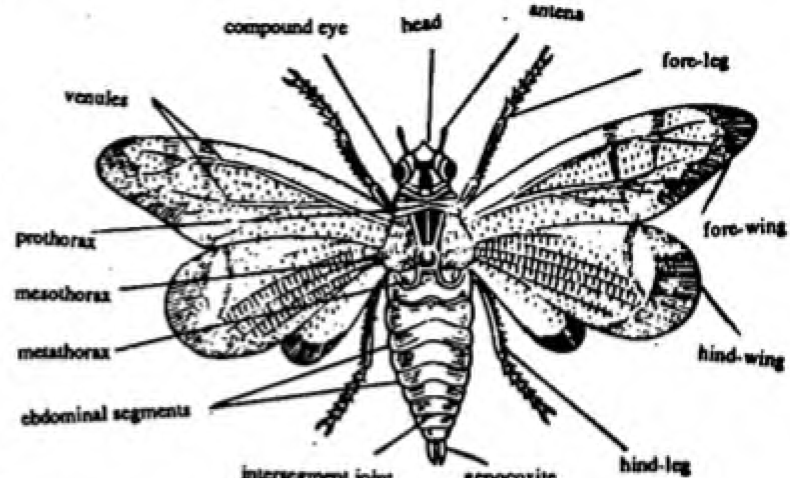


Fig. 46.36 *Cicada.*

4. The thorax comprises prothorax, mesothorax and metathorax.
5. There are two pairs of wings: fore-wings are larger and somewhat triangular and the hind-wings are oval.
6. The andomen is elongated and consists of ten segments.
7. The sound production habit of this insect is very peculiar.
8. The sound is produced only by the male which possesses a drum-like apparatus called aedeaugs.
9. Metamorphosis incomplete, egg hatches into nymph.
10. The life-history is very interesting as it takes about 13 to 17 years to complete.
11. Adults soon dies after mating.

APHID

The systematic position is the same as that of *Nepa*.

1. It is ectoparasite on plants sucking their juice. It is found specially on the plants of mustard, wheat and cotton.
2. It is commonly called 'plant-lice'.
3. Body is short divisible into head, thorax and abdomen.
4. Head is distinct with long straight antennae. Eyes are small.
5. Mouth parts are piercing and sucking type.
6. Thorax and abdomen robust. Abdomen is elongated.
7. Exhibit alternation of sexual and parthenogenetic phases, females always develop from parthenogenesis.
8. Both apterous and winged forms.

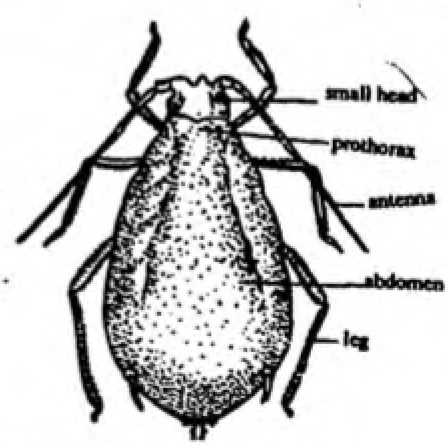


Fig. 46.37 Apple-grain *Aphid.*

DANAUS

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endopterygota
Order	-	Lepidoptera
Genus	-	*Danaus*

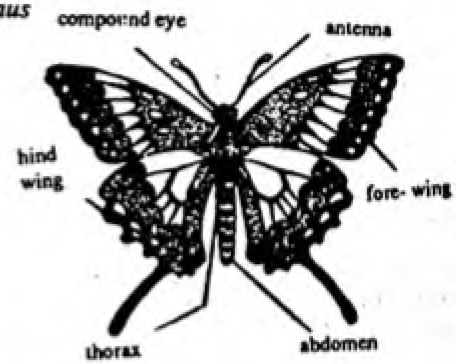


Fig. 46.38 *Danaus.*

1. It is a flying, terrestrial, diurnel insect found in gardens.
2. Commonly called butter-flies.
3. Beautifully and brightly coloured insects.
4. Body is divisible into head, thorax and abdomen.
5. Head with a pair of compound eyes and club-shaped antennae.
6. Mouth parts siphoning type. Maxillae are modified to form sucking tube.
7. Prothorax is fused with mesothorax.
8. Two pairs of wings which are typically covered with scales.
9. Abdomen is 10 segmented and covered with scales.
10. Cerci and ovipositor are lacking.
11. Development complete.

MOTH

The systematic position is the same as that of *Danaus.*

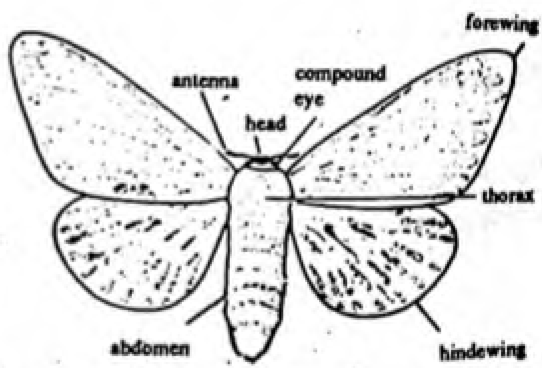


Fig. 46.39 *Moth.*

1. It is found in garden among flowering plants. It is nocternal in habit.
2. Body is broad and stumpy.
3. Body is divisible into head, thorax and abdomen.
4. Head bears a pair of eyes and antennae. The antennae are usually feather-like and terminal knobs are absent.
5. Wings two pairs and are held horizontally in resting condition and covered with scales.
6. Mouth parts are siphoning type.
7. Abdomen is 10 segmented.

COCCINELLA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endopterygota
Order	-	Coleoptera
Genus	-	*Coccinella*

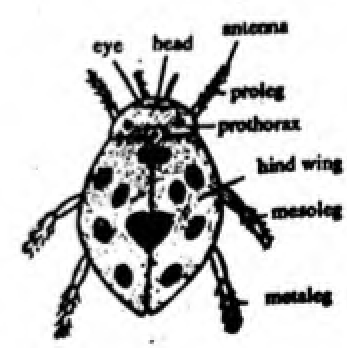


Fig. 46.40 *Coccinella.*

1. These are commonly called, 'Lady Bird - Beetle'. These are terrestrial animal.

2. Body divisible into head, thorax and abdomen.
3. Head incompletely hidden by pronotum.
4. Head bears compound eyes and a pair of antennae. Mouth parts are chewing type.
5. Large number of species are carnivorous and predacious. Feeds on aphids, coccids and other soft bodied insects.

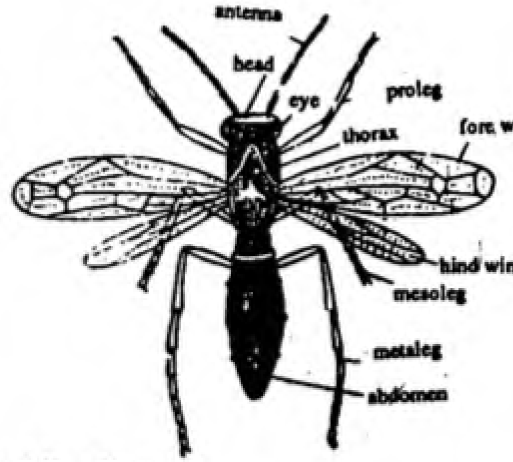


Fig. 46.41 *Vespa.*

VESPA

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endoptezygota
Order	-	Hymenoptera
Genus	-	*Vespa*

1. It is an Indian hornet, which is usually chestnut red and makes large nests of mud over walls and trees.
2. Body strongly built, usually chestnut red in colour with yellow, transverse bars.
3. Body is divisible into head, thorax and abdomen.
4. Head is globular concave posteriosly with small ocelli and compound eyes.
5. Thorax deep and cubical wings are membranous. Hindwings short and bear hooks on their anterior margin which fit into a groove on the posterior margin of forewings.
6. The abdomen petiolate, large with pointed apex.
7. Modified ovipositor as sting is present. It stings painfully and causes local pain and swelling.
8. *Vespa orientalis* is a social colonial insect. Colony consists of queen males and workers. The impregnated female hibernates in winter and forms a new colony at the next spring.

CAMPONOTUS

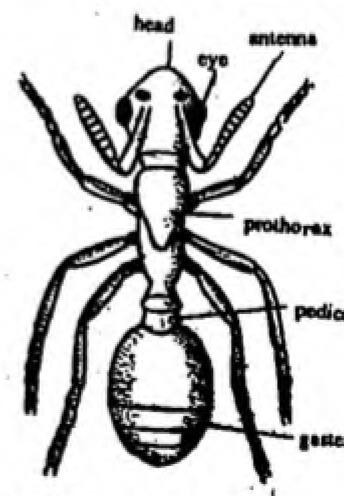


Fig. 46.42 *Camponotus.*

The systematic position is the same as that of *Vespa.*

1. Usually social insects live in burrows, holes, cervices etc.
2. Body divisible into head, thorax and abdomen.
3. Head varies in shape and mandibles are variable in forms.
4. Antennae consists of 4-13 segments. Male has one more segment than the female.
5. Compound eyes and ócelli are well developed in males where as reduced or vestigial in females and workers.
6. Stridulatory (sound producing) organ is present is abdomen.
7. Large and well developed stings are present in females and workers.
8. Mating takes place in winged stage during nuptial flight wings are then lost.
9. These are scavanger but are also harmful to man by destroying grain and seeds.
10. Other common Indian ants are: *Oceophylla smaragetina* (Weaver), *Holeomyrmex* (harvester) and *Formica* (red ant).

XENOPSYLLA

Phylum	-	Arthoropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endopterygota
Order	-	Siphonoptera
Genus	-	*Xenopsylla*

1. It is a sanguivorous ectoparasite of rats, birds and man.
2. It is commonly found in India, Sri Lanka and Malaysia.
3. It is commonly called 'rat-flea'.
4. Body is laterally compressed without wings.
5. Integument is covered with spines and bristles.
6. Head broad jointed with small thorax. Abdomen is very large.
7. Antennae are clavate, short and concealed in grooves.
8. Compend eyes and ocelli are absent.
9. Mouthparts piercing and sucking type.
10. Walking legs are elongated, clawed and modified for jumping.
11. It transmits 'plague' from rat to man.

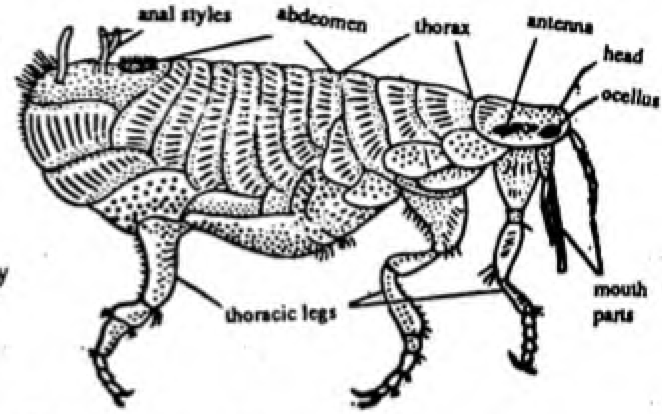


Fig. 46.43 *Xenopsylla.*

ARANEAE

Phylum	-	Arthropoda
Class	-	Arachnida
Order	-	Araneida
Genus	-	*Araneae*

1. It is found in houses and gardens.
2. It is commonly known as 'orb-webbed spider'.
3. Body consists of cephalothorax or prosoma and abdomen or opisthosome, the two being connected by a narrow pedical.
4. Prosome with simple 8 eyes and 6 pairs of appendages. A pair of subchelate chelicerae, a pair of nonchelate pedipalps and 4 pairs of walking legs.
5. Opisthosome is unsegmented, bears three pairs of spinnerets which produce thread for making web.
6. Poison glands open on the fangs of chelicerae.
7. Respiration by book-lungs and tracheae.
8. Excretion by coxal glands and Malpighian tubules.
9. Sexes are separate. Female is larger than male and eats up after copulation.

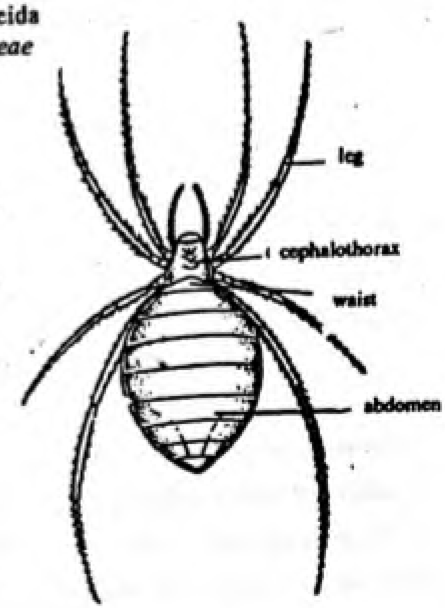


Fig. 46.44 *Aranea.*

SARCOPTES

Phylum	-	Arthoropoda
Class	-	Arachnida
Order	-	Acarina
Genus	-	*Sarcoptes*

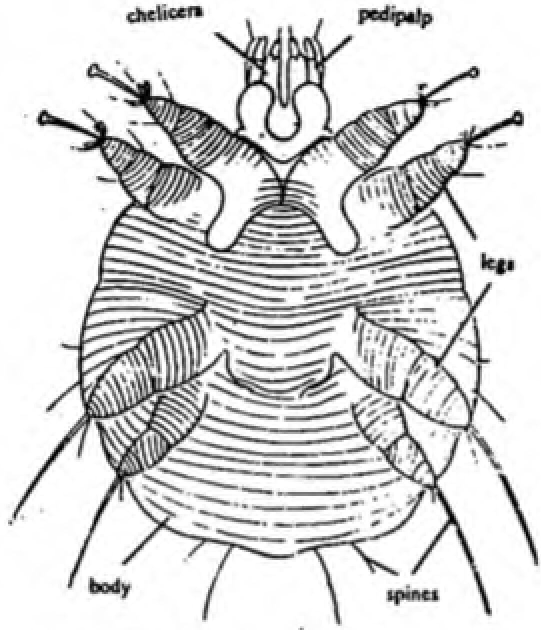


Fig. 46.45 *Sarcoptes.*

1. It is an ectoparasite on human skin and causes horizontal burrows in region between fingers, elbow etc. Leads to echzema. Commonly known as 'itch-mite of human'.
2. It is rounded or oval and dorsoventrally flatenned with transverse striations and short spines.
3. Prosoma and opisthosoma not differentiated.
4. Four pairs of legs. Anterior two legs are stronger and project beyond the body and provided with terminal stalked suckers. Posterior two legs are shorter and attached more ventrally and carry long bristles.
5. Mouth parts borne on capitulum, chelicerae chelate.

IXODES

The systematic position is the same as that of *Sarcoptes.*

1. It is an ectoparasite of sheep and commonly known as 'tick'.
2. Body ovoid, dorsoventrally flatenned and unsegmented.
3. Capitulum projects from the anterior end of the body and bears chelicerae and pedipalpi.
4. Dorsal surface of body is covered by shield-like scutum.
5. Eyes lateral and borne on scutum.

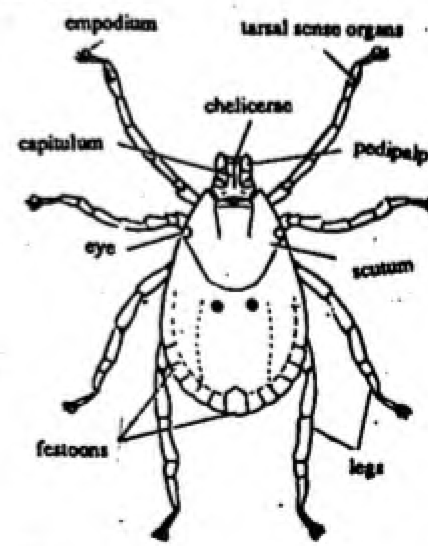


Fig. 46.46 *Ixodes.*

6. Walking legs 4 pairs with adhesive pads and claws.
7. Anus with adanal shield.
8. Female is larger than male.
9. They produce ixodin which acts as anesthetic, so that the host does not feel pains.

CHELIFER

Phylum	-	**Arthropoda**
Class	-	**Arachnida**
Order	-	**Pseudoscorpionida**
Genus	-	*Chelifer*

1. It is found commonly under the bark of trees.
2. Minute animals which have the appearance of scorpion but without tail hence commonly called 'pseudoscorpion'.
3. Body consists of prsoma and an opisthosoma.
4. Prosoma is broad and continuous bearing 6 pairs of appendages.
5. The chelicerae small 2 jointed and chelate.
6. Pedipalpi 5 jointed large and claw-like.
7. A pair of spining glands open on the tips of chelicerae.
8. Abdomen is 12 segmented.
9. Respiration by tracheae.
10. Males have a pair of reversible organ 'ram's horns, supposed to be copulatory in function.

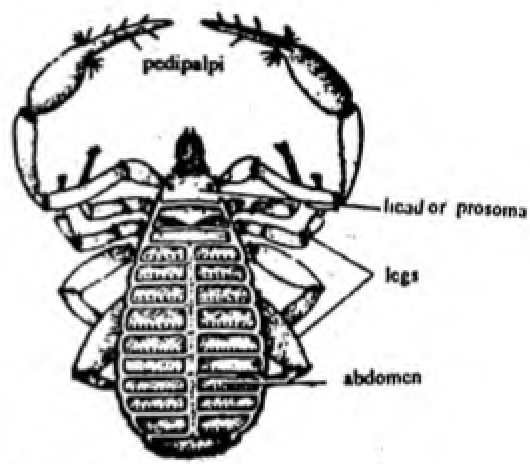


Fig. 46.47 *Chelifer.*

47

PALAEMON

Palaemon, commonly known as *prawn*, is found in fresh water streams, ponds, rivers etc. It serve as a good example to exhibit the characteristics of class Crustacea.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Crustacea
Subclass	-	Malacostraca
Order	-	Decapoda
Suborder	-	Macrura
Genus	-	*Palaemon*

HABITS AND HABITAT

A number of species of *Palaemon*, such as *P. carcinus*, *P. malcolmsonii* etc., are found in the fresh water streams, ponds etc. of India, Bangla Desh and distant countries such as West Indies, Mexico and Australia. These animals generally like slow-running waters and are bottom-feeders. They are nocturnal in habit and come out in the night in search of food. The food is generally algae or other water plants and sometimes, insects. *P. malcolmsonii* breeds in May, June and July and the females carry eggs attached to their abdominal appendages.

EXTERNAL MORPHOLOGY

Shape and Size. Prawn is a bilaterally symmetrical animal. The body is elongated and spindle-shaped and is well-adapted for swimming in water. The size of the adult *Palaemon* varies considerably in different species. *P. carcinus* measures about 75 cm in length (found in Travancore). *P. malcolmsonii* from Central India, Tamilnadu and Bengal is about 25-30 cm in length *P. lamarri*, common in lakes and ponds is quite small about 2.5 - 5 cm in length. *P. vulgaris*, a common prawn of America, measures 30 mm in length.

Colouration. The embryonic stages of prawn are usually translucent and whitish in colour. Adult animals of different species are of different colours. It is pale-yellow or greenish with a brown tinge or with orange-red patches or dull pale-blue.

Division of body. The body is divisible into two district regions:-

I. Anterior, immovable and unjointed cephabothorax.

II. Posterior, morable and jointed abdomen.

I. ***Cephalothorax.*** It is rigid and immovable. It is straight and oval in cross section. It is composed of 13 segments. In the embryonic condition, cephalothorax consists of first 14 fused segments and a pre-segmental region. Later on during development, first segment of the embryo disappears in the adult, while 13 segments remain. There are 13 pairs of appendages in these thirteen segments. The presegmental region is also found in adults and it possesses a pair of stalked compound eyes.

The cephalothorax is covered by a large chitinous shield, comprises two parts: *dorsal shield* and the *sternal plates*. The

dorsal shield further consists of anterior *dorsal plate* and posterior *carapace* but there is no line of demarcation between two. The dorsal plate is triangular and it extends forwards as a laterally compressed process, the *rostrum*. The upper and lower margins of the rostrum are serrated and densely fringed with setae. At the base of rostrum, on either side, there is an *orbital notch* to which movable jointed stalk of the compound eyes is attached. Just below each orbital notch, the dorsal plate bears a prominant *antennal spine*. Behind each antennal spine there is a relatively small *hepatic spine*.

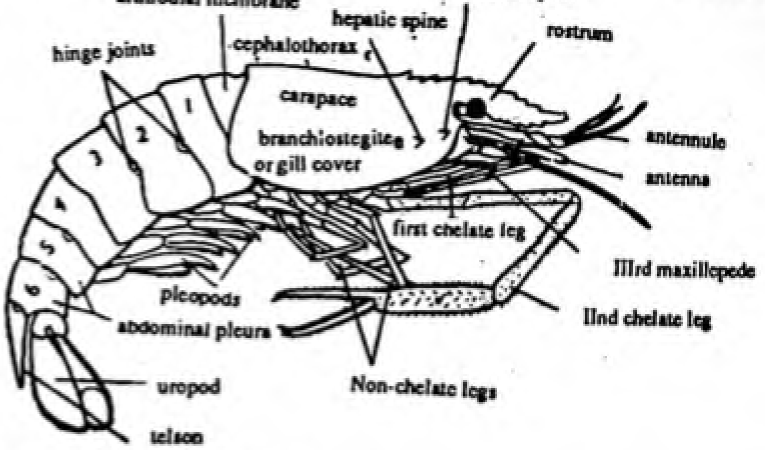


Fig. 47.1 *Palaemon*. Lateral view.

The carapace covers the thorax dorsally and laterally and represents the fused thoracic terga and pleura. On either sides of the body, the carapace hangs freely as a convex gill cover or *branchiostergite*. These enclose a narrow gill-chamber, which protects gills beneath them.

II. ***Abdomen***. It consists of 6 posterior movable segments and a terminal conical structure, the *telson*. The telson articulates with the 6th abdominal segment by a pair of hinge - joints.

Each abdominal segment is covered dorsally by a convex sclerite, the *tergum* and ventrally by the *sternum*. The tergum extends downwards on either side as a free flap, the *pleuron*. The pleuron covers the base of the appendage of its side, and is connected with it by a small sclerite, the *epimeron*. Pleura of the 2nd abdominal segment are largest and differ from others in overlapping the pleura of both the 1st and the 3rd segments. Pleura of the 6th segment are small and point backwards. The adjacent terga and sterna are connected by flexible *arthroidal membranes* of uncalcified cuticle. The adjacent terga articulate by a hinge-joint on either side. However, the hinge joint between the 3rd and 4th segments are lacking. These joints allow only up and down movement of the segments.

External apertures. Mouth is silt-like aperture opening mid-ventrally at the anterior end of the cephelothorax. It is surrounded by maxillipedes and maxillae. *Anus* is in the form of a longitudinal aperture situated ventrally at the base of telson. One pair of *renal apertures* open on raised papillae on the inner surface of the antennae. Sexes are separate. Paired *female genital apertures* are located on the inner surface of coxae of the third pair of walking legs in female. The paired *male apertures* are located on the inner surface of coxae of the 5th pair of walking legs in male. The openings of the statocysts open in a deep depression dorsally on the basal segment of each antennule.

APPENDAGES

The appendages of prawn show considerable diversity in structure. In different regions of the body appendages are well-adopted for different functions. These appendages are homologous as all have the same typical structure and development.

Appendages appear very different from one another can be reduced to a general type of appendage called, *stenopodium*. A stenopodium consists of two parts (i) *protopodite* or *sympod* or *stalk* and (ii) *rami* supported on the protopodite. The protopodite is a 2 jointed structure the proximal podomere with which the appendage is attached to the body is *coxopodite* or *coxa* and the distal joint is known as *basipodite* or *basis*. Rami are leaf like structures the outer one is called *exopodite* and inner one is *endopodite*. When there is only one ramus the appendage is called *uniramous* and when both are present it is a *biranous* appendage.

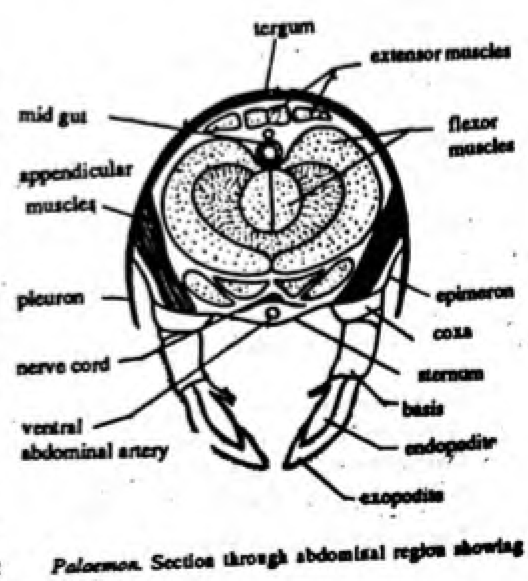


Fig. 47.2 *Palaemon*. Section through abdominal region showing sclerites.

There are 19 pairs of appendages which can be studies under 3 headings.

I. Cephalic appendages.

II. Thoracic appendages.

III. Abodominal appendages.

I. Cephalic appendages

As in all arthropods, there are 6 segments of the head. On the first there is a pair of compound eyes. These are not serially homologous with the other appendages, since they arise in a different way. Thus there are 5 pairs of appendages in cephalic region. These are antennules, antennae, mandibles, maxillulae and maxillae.

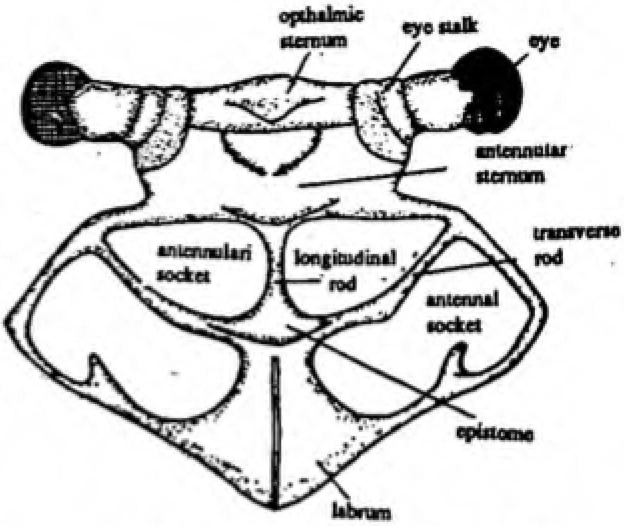


Fig. 47.3 *Palaemon*. Front view of preoral region.

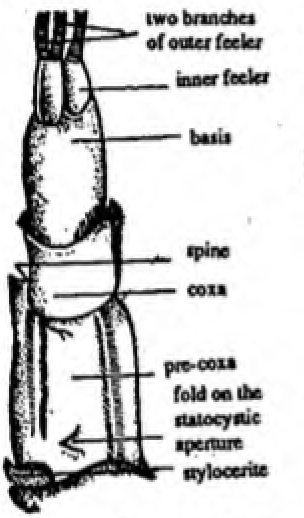


Fig. 47.4 *Palaemon*. Antennule.

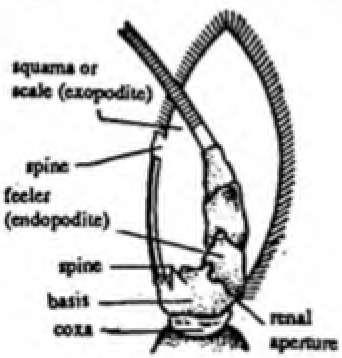


Fig. 47.5 *Palaemon*. Antenna.

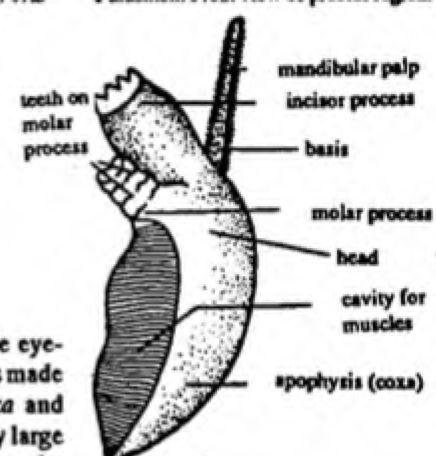


Fig. 47.6 *Palaemona* Mandible

1. *Antennules.* These are just beneath the eye-stalks. Each consists of a protopodite, which is made up of three podomears called *precoxa*, *coxa* and *basis*. The basal podomere, the precoxa is very large and hollow. The cavity of precoxa lodges the *statocyst*, whose opening is situated near its proximal end. From the outer margin of precoxa arises a spiny lobe, the *stylosclerite*. The coxa is short and cylindrical. It bears setae on its inner and anterior borders. The basis is longer than the coxa and lacks setae. It bears a pair of long, slender, many-jointed, tapering processes, the *feelers*, with swollen bases. The inner feeler is unbranched but the outer one is divided into two unequal branches, the inner smaller branch bearing special olfactory setae. It is wrong to regard the two feelers as the two rami of biramous limb, perhaps they represent only the endopodite subdivided.

2. *Antennae.* The antennae belong to segment 3, each with one feeler, situated immediately below and behind the antennules. The protopodite has two podomears, the coxa and basis. Each one is swollen at the bases as it lodges the renal glands within. The coxa is small in size and bears the renal aperture on its inner margin. The basis bears two rami: a long, slender, many jointed *feeler* with a swollen basis and a broad leaflike *squama*. Of these the feeler corresponds to the endopodite and the squama the exopodite. Squama acts as a balancer in swimming, is fringed with setae along its inner border. Its outer border is smooth terminating in a small spine in front.

3. *Mandibles.* The mandibles belong to the segment 4, lie on the sides of the mouth. They are very stout and highly calcified. The protopodite has two podomeres coxa and basis. The coxa is very large and can be divided into two parts: Proximal, spoon-shaped hollow *apophysis* and the distal solid, *head*. The head is formed of two processes - a *molar process* having 5-6 yellow dental plates and a plate like *incisor process* ending in three teeth. Each mandible bears three segmented *mandibular palp* that arises from the outer border of the head. The basal segment of the palp represents the basis of protopodite, the outer two

segments represent the endopodite, and the exopodite is absent.

4. *Maxillulae.* These are small thin, and leaf-like appendages of 5th segment. Coxa and basis are broad, and project inward as *gnathobases* or *jaws* fringed with bristles. Endopodite forms a curved process bifurcated at the apex. The exopodite is absent. The maxillulae halp in the manipulation of food.

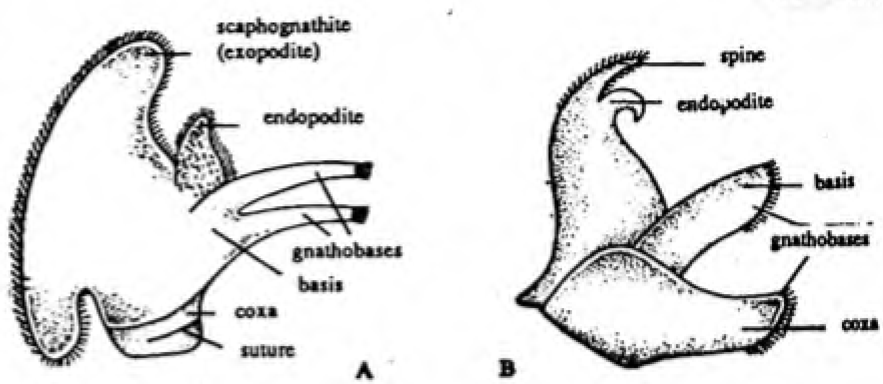


Fig. 47.7 *Palaemon*. A—Maxilla, B—Maxillula.

5. *Maxillae.* These are thin, flatenned and delicate leaf-like structure present in the last cephalic segment. Coxa is small and incompletely divided into two representing a fusion of procoxa and coxa. The basis is large and produced into a forked and strongly setose gnăthobase, the limbs of the fork are called *endites*. Endopodite is small and unjointed but the exopodite is large, flatenned and fan-like called *scaphognathite*. The movement of scaphognathite create a water current passing over the gills. It also bears sensory setae along its free margin. The maxillae help in manipulation and respiration.

II. Thoracic Appendages

There are 8 pairs of thoracic appendages in prawn. Anterior 3 pairs are called *maxillipedes* are remaining 5 pairs of *palaeopods* or *walking legs*.

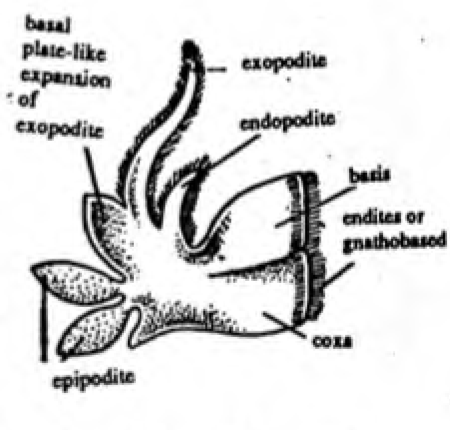


Fig. 47.8 *Palaemon*. I. Maxillipede.

1. *First maxillipedes.* These are foliaceous. The coxa and basis of their protopodite extend inwards as two gnathobases, each bearing two rows of spines on the inner border. Coxa bears externally a bilobed *epipodite* or primitive gill. The endopodite and exopodite are unjointed and bear setae.

2. *Second maxillipedes.* The protopodite is represented by a coxa, which is short and bears setae on the inner side and a small epipodite and a gill on the outer border. Basis is short and is immovably joined with the endopodite which consists of five podomeres: (i) *ischium*, (ii) *merus*, (iii) *carpus*, (iv) *propodus* and (v) *dactylus*. Last two are bent backwards and inwards. Exopodite is long, slender, unjointed and is fringed with setae. The functions of second maxillipede are also the same as those of the first maxillipede i.e. to help feeding as well as respiration.

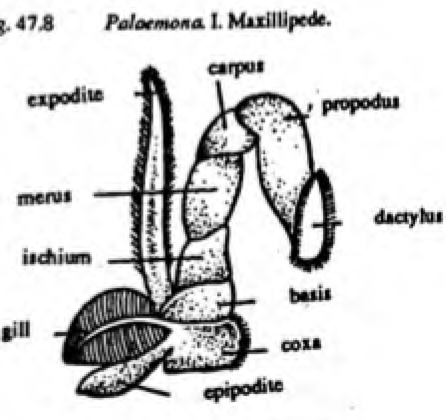


Fig. 47.9 *Palaemon*. II. Maxillipede.

3. *Third maxillipedes.* These are leg-like in appearance but possess same parts as 2nd maxillipedes. The coxa bears an *epipodite* on the outer side and setae along the inner border. The basis carries outer unsegmented *expodite* and an inner three-jointed *endopodite*. The first podomere represents fused ischium and merus, the 2nd carpus and the third represents fused propodus and dactylus.

4. *Walking legs.* The 5 pairs of walking legs differ from the maxillipedes in the absence of exopodite and epipodites. Thus they have two segmented protopodite and a five segmented endopodite. These 7 segments are arranged in row. The fourth pair of legs represent the typical structure. It contains all the 7 podomeres as *coxa, basis, ischium, merus, carpus, propodus* and *dactylus*.

In the first and second pairs of walking legs the propodus is prolonged distally beyond its articulation with dactylus and thus forms a long forceps-like structure. The structure is called *chela* or *pincer* and the leg is called *chelate leg*. The chelate legs are used to catch the prey and transfer it to the mouth and also serve as the organs of offence and defence. In male the 2nd pairs of chelate legs are larger and more stronger than that of female.

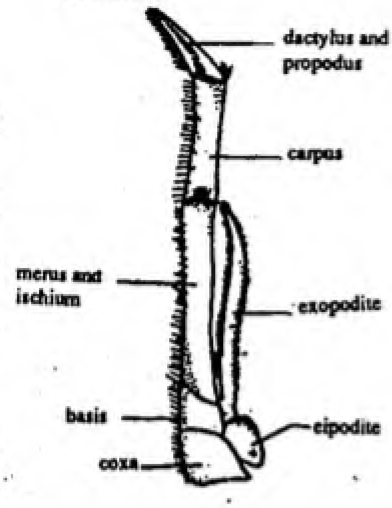


Fig. 47.10 *Palaemona.* III. Maxillipede.

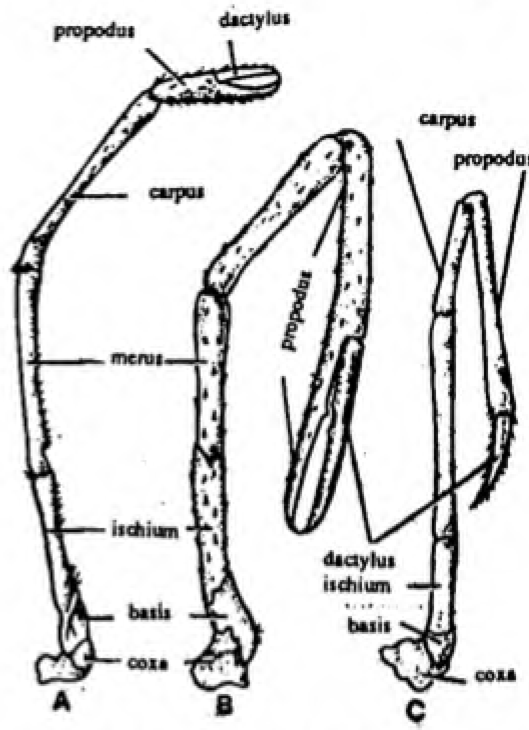


Fig. 47.11 *Palaemona.* A—I. Walking leg, B—II. Walking leg, C—Walking leg.

The third, fourth and fifth pairs of walking legs are typical and non-chelate. In female, each of the third leg bears a crescentic female genital aperture on the inner side of its coxa, while in male, each of the fifth leg bears a slit-like male genital aperture on its inner side of the arthrodial membrane connecting the leg and thorax.

III. Abdominal appendages

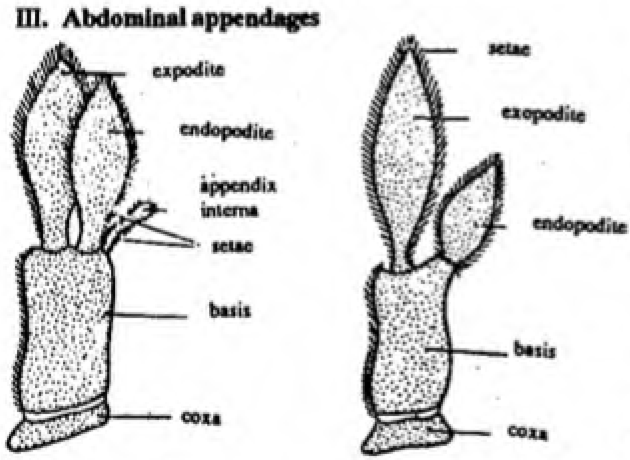


Fig. 47.12 *Palaemona.* A—Typical abdominal appendage, B—I pleopod.

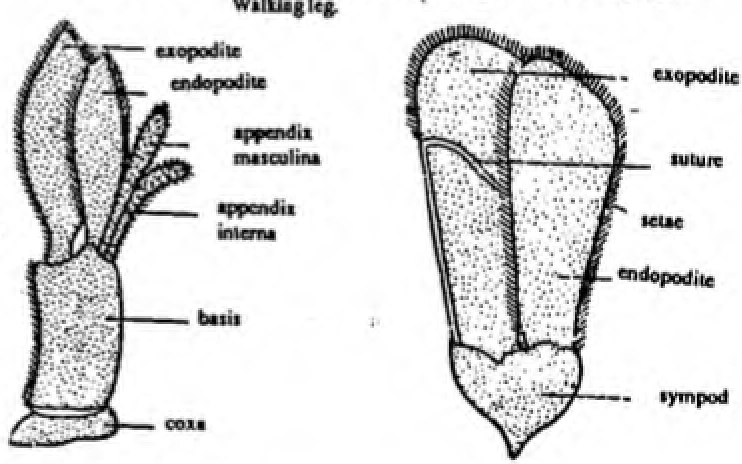


Fig. 47.13 *Palaemona* A=II pleopod, B= Uropod

There are 6 pairs abdominal appendages. These are collectively called *pleopods* or *swimmerets.* These are biramous appendages and help in swimming.

In a typical swimmeret (the 3rd abdominal appendage) the protopodite consists of two podomers, a short ring-like segment devoid setae known as the coxa and the basis which is cylindrical, bears setae on its surface and carries exopodite and endopodite. The endopodite is a leaf-like structure and gives of a small, rod-like structure, the *appendix interna,* with a knob-like head bearing many hook-like processes.

Differences from the typical swimmeret described above, are to be seen in the 1st, 2nd and 6th abdominal appendages of male and 1st and 6th of the female.

First abdominal appendages. In these endopodite is reduced and appendix interna is absent.

Second abdominal appendages of male. These are typical in female but in male the appendix interna gives off a rod-shaped process on its inner side called *appendix masculina.* It is covered with setae.

Sixth abdominal appendages. The sixth pair of abdominal appendages, called *uropods,* are large and lie one on either side of the telson forming *tail-fin* which enables the prawn to take a backward stering in water. The coxa and basis fuse together to form a triangular *sympod,* bearing the oar-shaped endopodite and exopodite. The exopodite is bigger than the endopodite and incompletely divided in the middle by a transverse suture. Their margins, except the outer border of the exopodite, are fringed with numerous seatets.

BODY WALL

The body wall of *Palaemon* consists of an outer layer of *cuticle* a middle-single layered *epidermis* and an inner *dermis.*

1. **Cuticle.** The cuticle of the body wall has become transformed into the exoskeleton which is thick and rigid at some places and thin and membranous at others. Cuticle is composed of two layers: (i) the outer layer is a thin non-chitinous *epicuticle.* It is yellow hyaline layer. It is further made up of two layers. Outer extremely thin made up of lipids and inner relatively thick protein layer. The protein layer is hardered and pigmented by its combination with an oxidised phenol. The epicuticle is secreted by the tegumental gland cells present is dermis. (ii) The *endocuticle* contains layers of chitin and has three successive layers: the outermost layer is a thin pigmented layer, below it is thick calcified layer and under it is an uncalcified layer. The pigmented layer is dark due to protein deposits and it becomes hardened by a process of tanning or sclerotization. In the calcified layer are deposits of carbonates and phosphates of calcium which make the integument hard. The chitin is an acetate of a polysaccharide containing glycosamine secreted by the underlying epidermis. The cuticle is relatively impermeable, except where it is thin and allows the passage of gases or absorption of water.

The seate and spines are the outgrowths of cuticle and have the same structure.

2. **Epidermis.** It comprises a single layer of glandular columnar epithelium resting on a thin basement membrane which is secreted by the underlying dermis. The epidermis is often called *chitogenous* epithelium as it secretes chitin.

3. **Dermis.** The dermis is thin and is made up of loose connective tissue beast with blood lacunae. It contains three types of tegumental glands that open out by fine ductules passing through overlying epidermis and the cuticle.

Table 47.1 Appendages of Prawn

Body Region	No	Name of Appendage	Protopodite	Endopodite	Exopodite	Special features	Functions
	1.	Antennules (pre-oral)	Consists of three podomeres, (a) Pre-coxa (b) Coxa, and (c) Basis.	Long, jointed feeler with swollen base.	Represented by an outer feeler which is further divided into an inner smaller branch and an outer large branch.	Precoxa has a cavity in which statocyst lodged.	Tactile, is olfactory and equilibrium
	2.	Antennae (Pre-oral)	Two podomeres: (a) Coxa, and (b) Basis.	Represented by a longer feeler having three podomeres.	Flat, broad, leaf like squama or scale.	Both coxa and basis are swollen due to the excretory organ with them. Coxa possesses a renal opening.	Sensory, excretory and balancing.
Cephalic appendages (5)	3.	Mandibles (post-oral)	Coxa large, spoon-shaped and densely calcified, Basis consists of two Parts:- (a) apophysis, and (b) head with molar process and incisor process. Basis is short	Represented by a mandibular palp which is two jointed.	Absent.	Coxa-teeth are located at the side of the mouth.	Mastication of food
	4.	Maxillulae (post-oral)	Coxa and basis both are leaf-like and project as gnathobases covered with pointed spines.	Bifurcated process on the outer side of the basis.	Absent.	Manipulation of food.	
	5.	Maxillae (post-oral)	Coxa is incompletely divided while basis forms a bifurcated gnathobasis.	Reduced to a small process which is narrow and is forwardly direct.	Flat, fan-shaped scaphognathite	Scaphognathite produces currents of water over gills.	Respiration and manipulation of food.

Body	No	Name of	Protopodite	Endopodite	Exopodite	Special features	Functions
	6.	1st Maxillipede	Coxa and basis project like jaws	Endopodite is represented by a small, unjointed appendage.	Exopodite is also unjointed and a plate-like expansion.	Similar to a leaf in shape	To hold food and tactile.
	7.	2nd Maxillipede.	Protopodite is represented by coxa which is short and bears setae on the inner side, and a small epipodite and gill on the outer border. Basis is short and is immovably joined with the endopodite.	It consists of 5 podomeres 1. Ischium: 2. Merus. 3. Carpus. 4. Propodus. 5. Dactylus.	Represented by long, slender, unjointed and fringed setae.		To help in feeding.
Thoracic appendages (8)	8.	3rd Maxillipede	Coxa is short and possesses epipodite on the inner side. Basis is short and supports exopodite and endopodite.	It consists of 3 joints:- 1. Fused ischium and merus. 2. Carpus. 3. Fused propodus and dactylus. 4. Distinct podomeres, i.e., ischium, merus, carpus, propodus and dactylus	Absent.	Chela or pincer is present.	Catches and transfers the prey to mouth.
	9.	2nd Chelate leg.	"	"	"	"	Organ of offence and defence. Large in males.
	10.	3rd Nonchelate leg.	"	Propodus and dactylus do not form chela.	"	Chela absent. In female, coxa bears a female genital aperture Chela absent.	Walking
Thoracic appendages	11.	4th Nonchelate leg.	"	"	"	Chela absent.	Walking.
	12.	5th walking leg.	"	"	"	In male, there is a male genital aperture between the leg and thorax.	Walking
Abdominal appendages (6)	13.	1st pleopod or swimmeret	Ring-like coxa and cylindrical basis. Basis possesses two rami.	Small, leaf-like, possessing setae.	Large, leaf-like.		Swimming.
	14.	2nd pleopod.	"	In female, it helps to carry the eggs with 3rd, 4th and 5th, appendix interna.	"	Appendix masculina is also present between endopodite and appendix, interna.	Appendix interna is present on the inner side on the endopodite as a short, slender, slightly-curved rod. Appendix interna is interlocked with its fellow of the opposite side to form a basket-like structure.
	15.	3rd pleopod.	"	"	"	"	"
	16.	4th pleopod.	"	"	"	"	"
	17.	5th pleopod.	"	"	"	"	"
	18.	Uropod or 6th swimmeret.	Coxa and basis fused to form a broad plate or sympod.	Flat, oval plate and provided with setae.	Large and divided into two pairs by a transverse suture.	With the telson form tail.	Swimming

BODY CAVITY

In *Palaemon* the body cavity is mostly occupied by musculature and organs (having interspaces containing blood) and all these together form a body cavity or haemocoel. However, true coelom is restricted to kidneys and gonads.

MUSCULATURE

The bulk of the body of the *Palaemon* consists mainly of muscles which are enclosed within the exoskeleton. These muscles are voluntary or striated type. The unstriated muscles are found in the orgns such as blood vascular system and digestive system. There are two sets of muscles in prawn, the *appendicular muscles* that are segmentally and the *abdominal muscles* for straightening and flexure of the abdomen. The muscles are arranged in opposing series. By the contraction of one set the limbs are flexed (*flexor muscles*) and by the contraction of other, the limbs return to their normal position (*extensor muscles*). In the abdomen too such muscles are found. In the terminal sclerite of chelate leg, the flexor muscle become *adductor*,

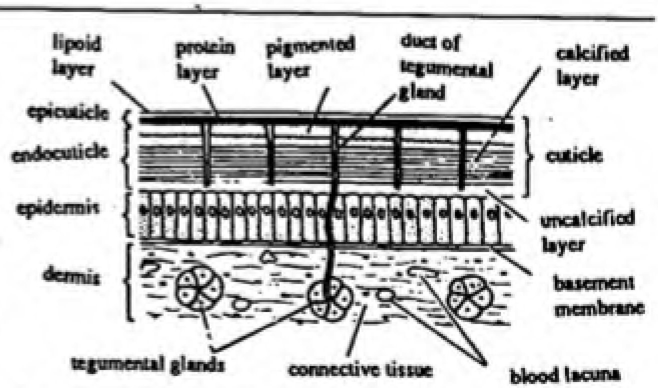


Fig. 47.14 *Palaemona.* V.S. of Skin.

closing the chela, and the extensor, *abductor*.

The extensor of abdominal muscles include a pair of *dorsal extensor*, four pairs of *intertergal abdominal muscles*, a pair of *intertergal muscles* and two pairs of *extensor* of the telson.

The flexors of abdominal muscles include 5 pairs of main flexor (first 5-segments), four pairs of *accessory flexor* muscles (first 4 segments), a pair of flexor (between first abdominal segment and thorax), two pairs of *lateral thoraco - abdominal* muscles, two pairs of flexor muscles of telson and a pair of *ventral superficial flexor* muscles.

All the appendages have their own muscles.

ENDOSKELETON

Palaemon has an endoskeleton in the cephalothorax formed of a series of ingrowths of the exoskeleton called ***apodemes*** or *endophragms*. These ingrowths are connected together to form a regular framework that is known as ***endophragmal skeleton***.

The endophragmel skeleton is well developed in the segments 11-13, where, in each segment, it consists of an outgrowth from the anterolateral end of epimeron of the same sternal segment called *endopleurite posterior*.

The endopleurite posterior meets an ingrowth from the posterior-lateral end of the epimeron of the segment in front, called *endopleurite anterior*. These in turn meet respective ingrowths of the sternum of the same segment an *endosternite posterior* and an *endosternite anterior*. From the mesosternite, on each side arises an upwardly directed 'Y' shaped plate. The inner limb of the Y is called *mesophragm* and outer *paraphragm*. These apodemes provide for attachment of abdominal flexor muscles while other apodemes are for the attachment of appendicular muscles. A typical apodeme with complete number of endosternites, endopleurites and Y shaped structure occurs only between 11th, 12th and 13th segments. In other segments the apodeme is incomplete.

In mandibular region there is a H-shaped structure, the *cephalic apodeme*, for the insertion of muscles of branchiostegites, small gastric muscles and the muscles of mandibles.

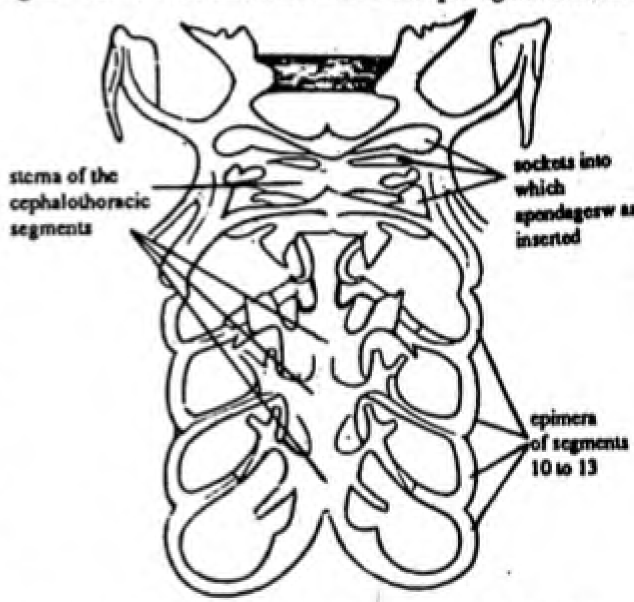


Fig. 47.15 *Palaemona*. The sterna and endophragmal skeleton (dorsal view).

DIGESTIVE SYSTEM

The digestive system comprises, alimentary canal and digestive glands.

1. **Alimentary Canal.** The alimentary canal is straight tube-like structure of varying diameters. It comprises:

   1. Foregut or stomodaeum.

   2. Midgut or mesenteron

   3. Hindgut or proctodaeum.

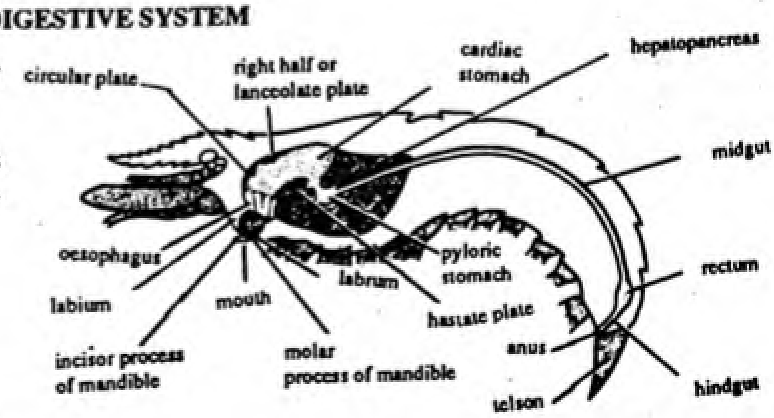


Fig. 47.16 *Palaemona*. Alimentary canal in lateral view.

1. ***Foregut***. The foregut comprises the mouth, buccal cavity, oesophagus and stomach. Foregut is ectodermal in origin hanace it is internally lined by

ectoderm and cuticle.

(i) *Mouth.* The mouth is large slit-like apertuse situated on the ventral side of the head below the anterior end. It is bounded anteriorly by a shield shaped *labrum* or upper lip. Laterally by the incisor processes of *mandibles* and posteriosly by a thin *labium* or lower lip which is bilobed. Mouth leads into the buccal cavity.

(ii) *Buccal cavity.* The buccal cavity is an antero-posteriorly compressed small chamber with irregularly folded thick chitinous lining. The *molar processes* of mandibles project into it and lie opposite each other.

(iii) *Oesophagus.* The oesophagus is a short, wide, vertical tube joined with the buccal cavity and stomach. Its inner wall is muscular and is produced into four longitudinal folds: an anterior fold which is short, a posterior fold and two lateral folds, which are large and more prominent.

The internal cuticle of oesophagus is covered with various bristels. Oesophagus opens into the stomach; the opening is provided with a valve like structure.

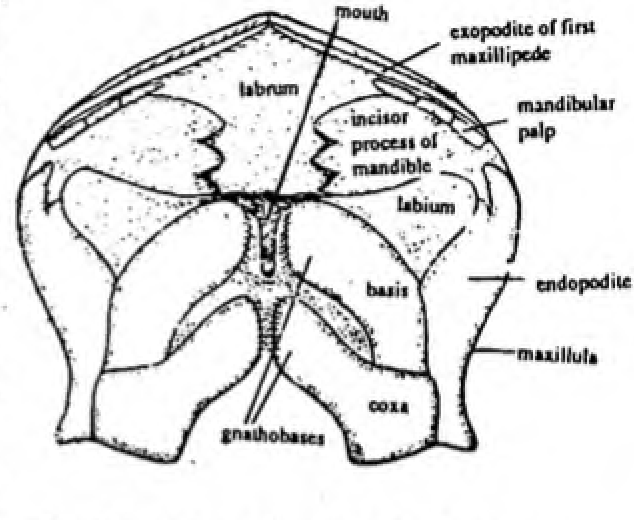


Fig. 47.17 *Palaemon.* Ventral view of oral region.

(iv) *Stomach.* It is a spacious chamber which occupies most of the cephalothoracic region. It is surrounded ventrally, laterally and posteriorly by hepatopancreas. The stomach is divided into two parts. (A) Cardiac stomach and (B) Pyloric stomach.

(A) *Cardiac stomach.* It is the anterior sac-like part of the stomach in which the layer of cuticle on the inner surface is raised into many fine and indistinct longitudinal folds which bear find bristles. The wall of stomach is supported by a number of cuticular plates. These plates are as follows:

(a) *Circular plate* is present in front of oesophageal aperture forming its anterior wall.

(b) *Lanceolate plate* is embedded mesially in the roof of the stomach just behind the circular plate.

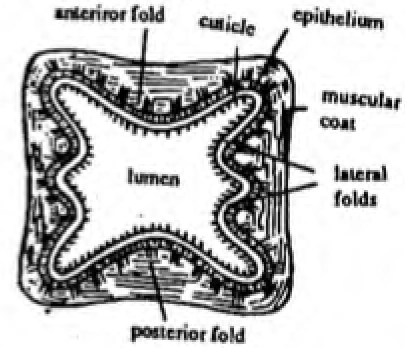


Fig. 47.18 *Palaemon.* T.S. of oesophagus.

(c) *Hastate plate* is a triangular plate embedded in the middle of floor of stomach. It is raised in the middle with sloping sides. Its upper surface is covered with a thick growth of delicate setae. The posterior broad margin is depressed and fringed with setae in to form the anterior valve of the cardio-pyloric aperture. The lateral margins of the hastate plate are supported by two circular *supporting rods.* A narrow lateral groove runs along the outer border of each supporting rod.

(d) *Groove plates* form the floor of lateral grooves and are in the form of open drain pipes.

(e) *Combed plate.* Each lateral groove on its outer side is supported by a long ridge plate or combed plate. The two combed plates are united anteriorly but remain separate posteriorly by cardio-pyloric aperture. The inner border of each combed plate is beset with a row of long delicate bristles which bridge over the lateral groove and partially overlap the lateral margins of the hastate plate. The bristles remain in constant movement.

Just outside the combed plates, the wall of cardiac stomach is folded on each lateral side to form *guiding ridges* or lateral *longitudinal folds.* These ridges are low in front but gradually increase in high behind, but posteriorly the high walls of these folds bend inwards over the cardio-pyloric aperture, forming lateral valves. Thus these valves guard the passage of food towards the cardio-pyloric aperture.

The cardio-pyloric aperture is narrow x shaped and is guarded by four valves, through which cardiac stomach opens into pyloric stomach.

(B) *Pyloric stomach.* Pyloric stomach is a short, narrow chamber. It is the posterior part of the fore-gut situated below the posterior end of the cardiac stomach. Its lateral walls are thick and muscular and project into the lumen as thick, longitudinal folds dividing it into a dorsal and a ventral chamber. These two chambers are connected by a narrow vertical passage. The floor of the ventral chamber is elevated into a median longitudinal ridge so as to form two lateral compartments. The floor is provided with an '^' shaped *filter plate* or *pyloric filter*. It bears a series of longitudinal ridges having bristles and grooves, which are felt-like. Thus, an efficient *strainer* or *filter* is formed, which allows only liquid food through it. At the posterior end of the chamber just behind the pyloric filter, there is a pair of small openings by which digestive juices from the hepatopancreatic duct are poured into the pyloric stomach. These openings are provided by posteriorly-directed setae, which act as valves to control the direction of the flow of the secretion.

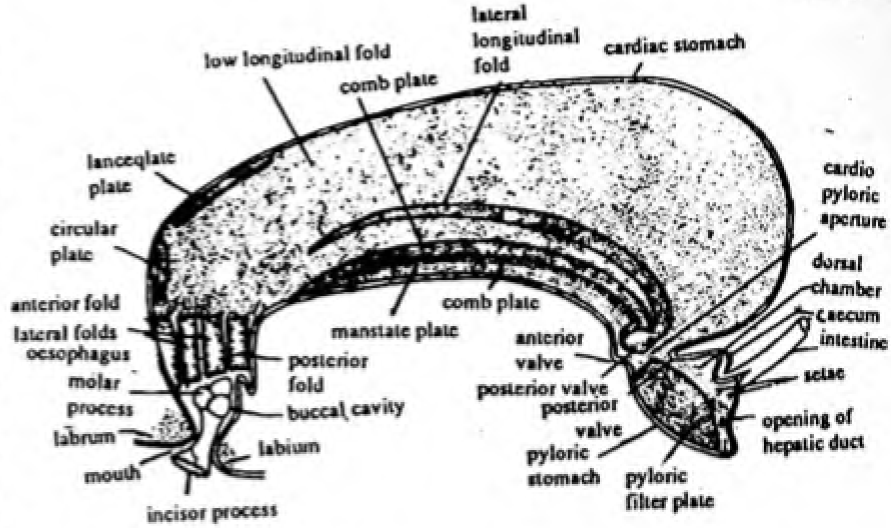


Fig. 47.19 *Palaemon* V.L.S. of Foregut.

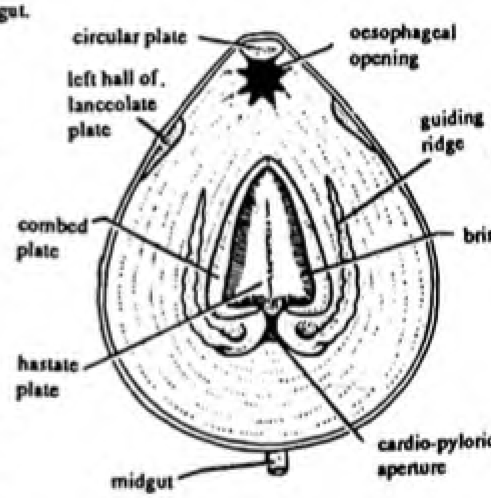


Fig. 47.20 *Palaemon*. Floor of cardiac stomach.

The dorsal chamber gives out a small blind caecum dorsally and opens into the mid-gut. The junction of dorsal chamber and midgut is guarded by the median dorsal and two lateral groups of elongated setae. These setae control the flow of food material.

(v) *Midgut or mesenteron.* The midgut is a long, narrow, straight and slender tube running back along the median line above the mass of the ventral abdominal muscles upto the sixth abdominal segment. The internal lining of midgut is formed by epithelium which in the posterior part is thrown into many longitudinal folds thus greatly reducing its lumen.

(vi) *Hindgut or proctodaeum.* It is the last part of alimentary canal which is internally lined with cuticle. Its anterior enlarged muscular part is called the *intestinal bulb* and the posterior less wide part is the *rectum*. It opens out through the anus which is placed at the base of the telson.

(vii) *Anus.* It is a longitudinal slit. It is surrounded by circular and radial muscle fibres. The former forms the sphincter and the later acts as dilator.

Histology. The wall of midgut consists of 4 layers. Beginning from inside, these are (i) An epithelial layer of tall columnar cells resting on a basement membrane, having

Fig. 47.21 *Palaemon*. A—T.S. pyloric stomach, B—A part of pyloric stomach.

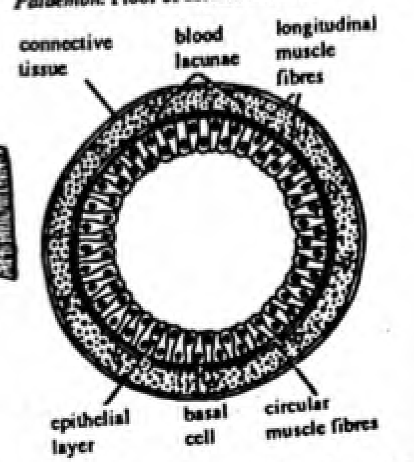


Fig. 47.22 *Palaemon*. T.S. of mesenteron

small basal or replacing cells (ii) A thin layer of circular muscle fibres (iii) A thick layer of longitudinal muscle fibres enclosing a plexus of blood lacunae (iv) A connective tissue sheath.

The rectum also has the same layers except that its epithelial lining is covered by cuticle and there is an additional layer of longitudinal muscle fibres inside the circular muscle fibres.

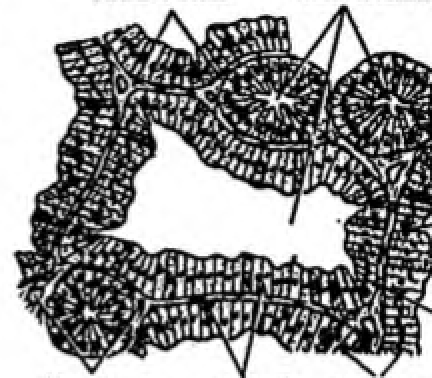


Fig. 47.23 *Palaemon.* T.S. of hepatopancreas.

II. **Digestive gland.** The *hepatopancreas* is a large and physiologically very important gland. It consists of a pair of orange-red coloured lobes lying close to each other surrounding the cardiac stomach and has a massive appearance. It is a racemose gland which arises as a pair of tubular outgrowths from the midgut. These outgrowths grow, divide and redivide, thus forming a compact network which is held together by connective tissue. The wall of each tubule forming the gland is made up of four layers: the inner most layer of epithelial cells, a thin basement membrane on which epithelial cells rest and the outer most layer or *tunica properia* formed of a network of connective tissue and muscle fibres. The epithelial layer has four kinds of cells (i) *Hepatic cells* which are columnar shape and with their cytoplasm filled with fat droplets (ii) Granular cells (iii) Irregularly scattered forment cells and (iv) Basal or replacing cells.

The hepatopancreas perform following functions:

1. It secretes enzyme for digestion of carbohydrates, fats and proteins.

2. It serves to store glycogen, calcium and fat.

3. It helps in absorption of digested food material.

Food and feeding. Palaemon is omnivorous, feeding upon aquatic weeds, algae, moss, insects and debris of bottom. It feeds at night. The chelate legs, aided by the third maxillipedes, capture and convey the food to the mouth. The coxae of the second maxillipedes hold the food, while the incisor processes of mandibles cut it into smaller pieces which are swallowed with the help of maxillipedes, maxillulae and maxillae. Inside the buccal cavity the molar processes of mandibles masticate the food, which is then conveyed to the cardiac stomach through the oesophagus.

Digestion. The digestion of food starts in the cardiac stomach where the hepatopancreatic juice from the pyloric stomach ascends up and mixes well with the food. Due to the alternate expansion and contraction of stomach wall the food is well churned. While passing over the hastate plate the food particles are still reduced to minor pieces so that the food is converted into a paste. This paste is filtered through the bristles of combed plate and is carried to the pyloric stomach. The food in the semi-liquid and semi-digestid condition is carried into the ventral chamber of pyloric stomach. The digested and liquified food is filtered through the pyloric filter and it again enters the hepatopancreas through the hepatopancreatic ducts and then becomes absorbed. The residual food material, consisting of undigested particles, passes on to the midgut and the remaining digested food is absorbed in the midgut. The undigested faecal matter pass on to the posterior side of the hindgut and ultimately expelled through the anus.

RESPIRATORY SYSTEM

The respiratory organs in prawn are developed and are located in the gill chambers, between the branchiostergite and the thorax. These are:

1. Brnchiostergic or gill cover.

2. Three pairs of epipodites.

3. Eight pairs of gills or branchiae.

1. **Branchiostergite.** The inner lining of branchiostergite is thin, membranous and highly vascular containing minute blood

lacunae. These are constantly bathed in fresh water, thus forming the respiratory surface through which exchange of gases takes place between blood and water.

2. **Epipodites.** These are thin, leaf-like processes, one attached to each maxillipede. These epipodites are full of blood lacunae and, infact, constitute a primitive type of gill. The epipodites lie in the anterior part of the gill-chamber below the scaphognathite. Exchange of gases between blood and lacunae takes place between water and blood in epipodites.

3. **Gills.** There are 8 pairs of gills. These arise from the modification of epipodites and according to their position, they be distinguished into three types:

(i) *Podobranch.* When a gill is attached to the coxa of an appendage, it is called podobranch or foot-gill. In *Plaemon* one podobranch is carried by the coxa of each 2nd maxillipede.

(ii) *Arthrobranch.* When a gill is attached to the arthrodial membrance connecting the appendage to the thorax it is called arthrobranch or joint gill. Each 3rd maxillipede bears two arthrobranches.

(iii) *Pleurobranch.* When a gill is attached to the lateral wall of the segment bearing limb, it is called pleurobranch or side gill. The last five gills on each side are pleurobranch attached to the lateral wall of the thoracic segments bearing five walking legs.

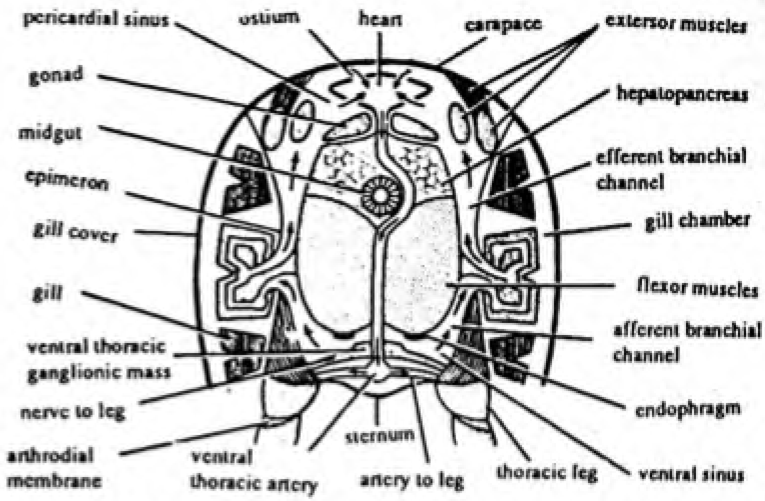


Fig. 47.24 *Palaemon.* Section through cephalsthorax showing gill chamber.

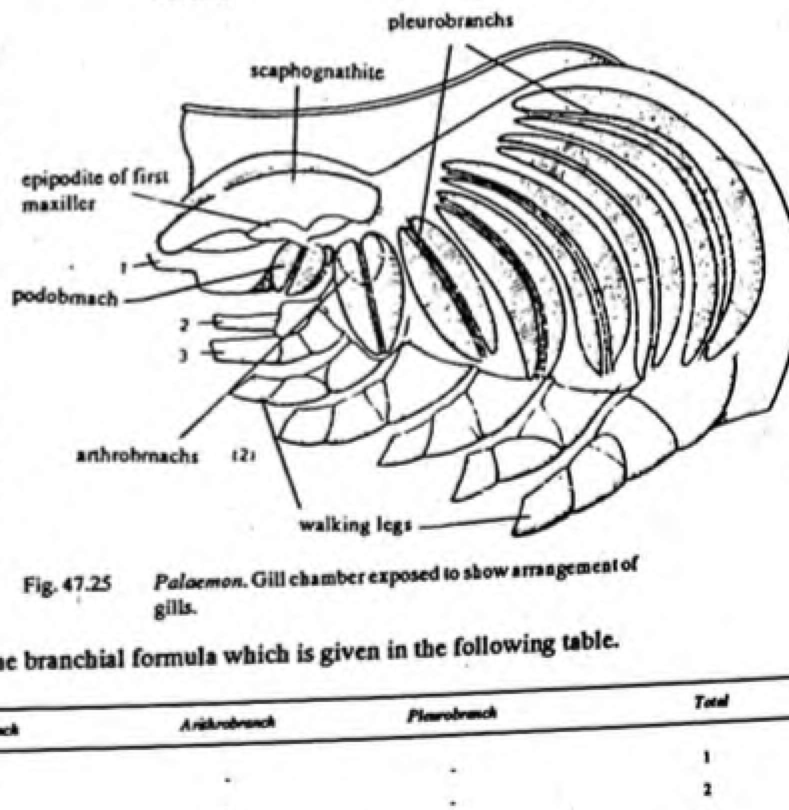


Fig. 47.25 *Palaemon.* Gill chamber exposed to show arrangement of gills.

Branchial formula. The number and position of epipodites and gills can be illustrated by the branchial formula which is given in the following table.

Appendage	*Epipodite*	*Podobranch*	*Arthrobranch*	*Pleurobranch*	*Total*
I Maxillepede	1	-	-	-	1
II Maxillepede	1	1	-	-	2
III Maxillepede	1	-	2	-	3
I Walking leg	-	-	-	1	1
II Walking leg	-	-	-	1	1
III Walking leg	-	-	-	1	1
IV Walking leg	-	-	-	1	1
V Walking leg	-	-	-	1	1
Total	3	1	2	5	11

Structure of gill. The gills are almost crescentic or semilunar in shape. Each gill consists of a *central axis* or base from which arise two rows of rhomboidal *gill-plates* or *lamellae*. Leaving a deep groove called *median longitudinal groove* between the two rows, such a gill is known as *phylobranch*. The gill plates found in the middle of gills are large and gradually become smaller toward both the ends. In the middle of gill arises a small structure called *gill-root* by which it is attached to the thorax. Nerves and blood vessels enter or leave the gill through the gill roots.

The base of the gill appears triangular in a cross section. It is made up of loose connective tissue which is bounded by epidermis and cuticle. There is a row of epithelial cells in each gill-plates, outside which is a thin layer of cuticle. The cells are of two types *viz. pigmented* and *transparent* alterning with each other.

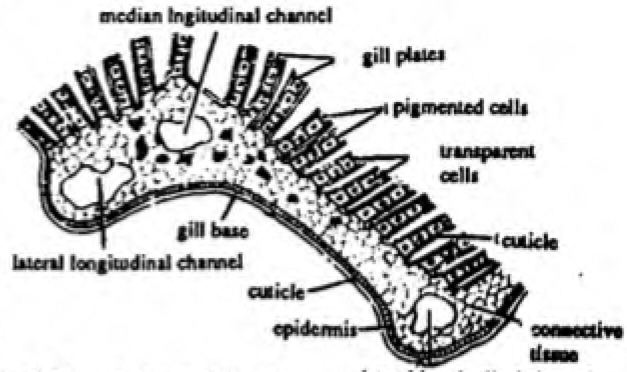


Fig. 47.26 *Palaemon*. T.S. of gill

Circulation of blood in gills. The gills are profusely supplied with blood. Three blood vessels run vertically in each axis - two *lateral longitudinal channals* along the two lateral margins and a *median longitudinal channel* in the middle. The lateral longitudinal channels are connected with each other by *transverse connective*, one of which, near the gill - root, communicates with the *affarent branchial* channel and receives blood from it. Each lateral channel gives a delicate marginal channel into each gill-plate which runs along the outer margin of the gill-plate and finally opens into the median longitudinal channel. Blood from the afferent branchial channel passes into the transverse connective from where it goes into the lateral longitudinal channel, then through the marginal channel into the median longitudinal channel which finally pours the blood, at the gill-root, into the *efferent branchial* channel by a short connection.

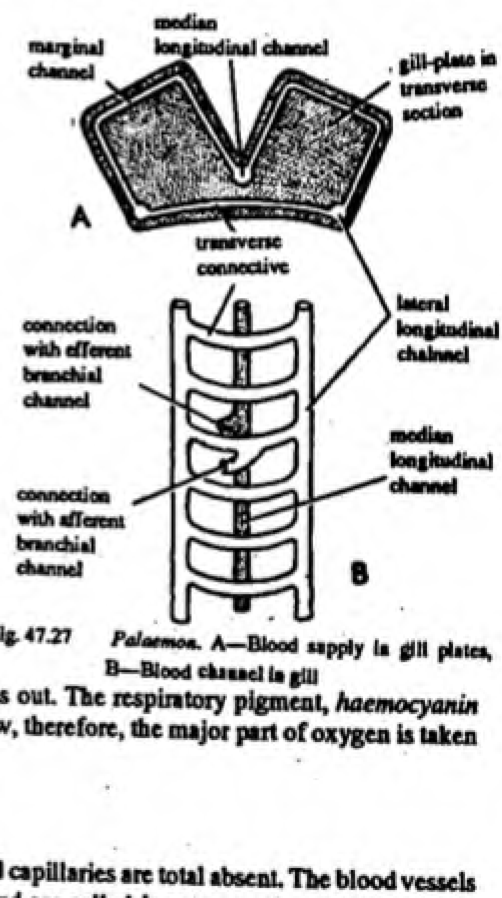


Fig. 47.27 *Palaemon*. A—Blood supply in gill plates, B—Blood channel in gill

Mechanism of respiration. The exopodite of maxilla, called scaphognathite, is so situated that its anterior end penetrates into gill chamber and the posterior end lies outside. The gill chamber itself is covered dorsally and laterally but is open ventrally. The vibrating action of the scaphognathite bales out water from the anterior end of the chamber and simultaneously pushed a water current movement of the baler results in continuous entry of fresh water from behind and its subsequent exit from front. The incoming water current not only passes over the gills, epipodites but also washes the branchiostergites. The oxygen dissolved in water is taken into the blood and carbon dioxide passes out. The respiratory pigment, *haemocyanin* remains dissolved in blood. However, the haemocyanin content in the blood is low, therefore, the major part of oxygen is taken in as simple solution in plasma.

CIRCULATORY SYSTEM

In prawn the circulatory system is *open* or *lacunar type*, in which the veins and capillaries are total absent. The blood vessels (arteries) open into spaces. These spaces are without a proper epithelial lining and are called *lacunae* or *sinuses*. The sinuses together form the body-cavity which looks like a coelom, but filled with blood and devoid of epithelial lining, is known as *haemocoel*.

The circulatory system in *Palaemon* consists of:

1. Pericardium

2. Heart

3. Arteries

4. Sinuses

5. Blood channels

6. Blood.

1. Pericardium. It is a wide thin-walled chamber around the heart and remains filled with *haemocoelomic fluid.* Its floor is in the form of a thin horizontal septum which lies just above the gonad and hepatopancreas and is attached to the dorsal body wall along its anterior and posterior aspects. The septum is attached to the lateral walls of the thorax along the lateral aspect. The pericardial cavity pumps blood into the heart.

2. Heart. The heart is a triangular, muscular structure with its broader base facing posteriosly and the apex in front. It is found in the pericardial sinus in the median dorsal part of thborax. A median longitudinal strand, the *cardiopyloric strand*, extending from the apex of the heart of the dorsal wall of the pyloric stomach, and two lateral strands, stratching from the lateral angle of the heart to the body wall, support the heart in the pericardium. The walls of the heart are very thick, muscular and extremely elastic. There are 5 pairs of valvular openings, the *ostia* in the wall of heart. The first pair of ostia is situated in the mid-dorsal region. The second pair is found mid-ventrally. The third pair lies on the posterior border. The fourth pair lie anterio-laterally and the fifth pair posterio-laterally. The cavity of heart is not continuous but is traversed by a large number of interlacking muscle fibres.

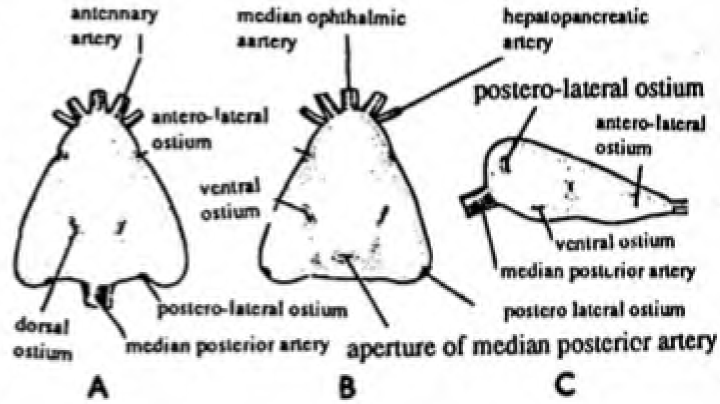


Fig. 47.28 *Palaemon*. Heart A—Dorsal view, B—Ventral view, C—Lateral view.

3. Arteries. The arteries are thick-walled muscular tubes, which arise from the heart and supply blood to different organs of the body. The main arteries are following:

(i) ***Median ophthlmic artery.*** It arises as a single median cephalic or ophthalmic artery from the apex of the heart. It runs forward to the head region in the mid-dorsal line above the renal sac. Here it joins the two antennary arteries.

(ii) ***Antennary arteries.*** A pair of them originate from the apex of the heart one from either side of the median ophthalmic. Each runs obliquely forward along the outer border of the mandibular muscle. During its course it gives out the following branches:

(a) *Pericardial branch* to the pericardium,

(b) *Gastric branch* to the cardiac stomach, and

(c) *Mandibular branch* to the mandibular muscles.

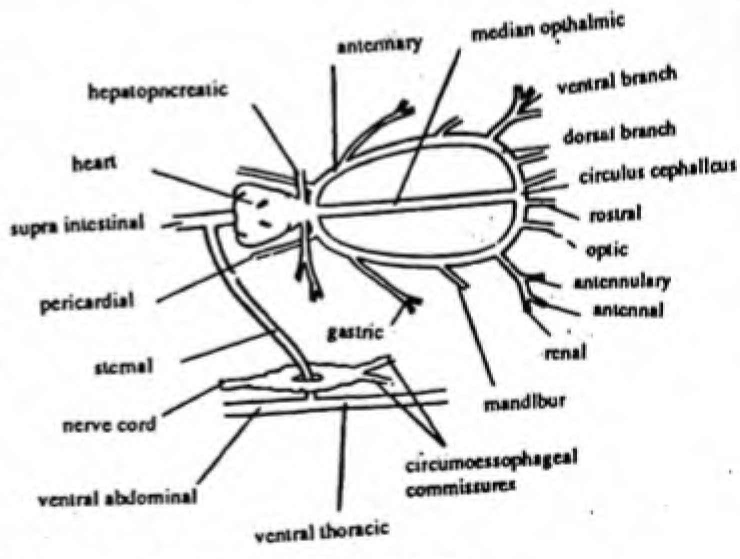


Fig. 47.29 *Palaemon*. Showing heart and arteries.

Each antennary artery passes forwards and divides into two sub-branches:

(a) *Dorsal branch.* It sends an *optic artery* to the eye and then bend inwards to meet its fellow of the opposite side forming

a circular loop-like artery the *cerculus cephalicus*, which gives off a pair of *rostral arteries* to the rostrum.

(b) *Ventral branch.* It is also divides into sub-branches, one of which supplies the antennule called *antennulary.* Second redivides into two an *antennal* to antenna and other *renal* to the renal organ.

(iii) ***Hepatic arteries.*** These are also paired arteries, which arise from the heart on the ventro-lateral sides of the roots of antennary arteries. They ramify into the hepatopancreas.

(iv) ***Median posterior artery.*** It is a small but stout artery which arises from the posterio-ventral surface of the heart and runs backwards. It immediately bifurcates into two branches.

(a) *Supra-intestinal artery.* The supra-intestinal artery passes stright backwards along the dorsal surface of the intestine extending up to the hind-gut, while it divides into two branches supplying blood to the intestine and the dorsal abdominal muscles.

(b) *Sternal artery.* The *sternal artery* is the stoutest of all others. It runs downwards and forwards through the hepatopancreas and after passing through an aperture in the middle of the ventral thoracic ganglionic mass to reach the ventral side, it gets divided into two branches. The *ventral thoracic branch* runs anteriorly up to the mouth and supplies the sternal region, first three pairs of walking legs, maxillae, and maxillulae, etc. The *ventral abdominal branch* runs posteriorly upto the anus and supplies blood to the ventral abdominal region, last two pairs of legs, pleopods and hind gut, etc.

4. **Blood Sinuses.** The various arteries, on reaching the organs, branch repeatedly into minute branches which do not form capillaries but end into wide spaces, *blood sinuses* or *blood lacunae.* All the blood lacunae of the body collectively form a pair of elongated but ill-defined *ventral sinuses.* These lie below the hepatopancreas and above the floor of thorax. The ventral sinuses communicate with each other at various places.

5. **Blood Channels.** In *Palaemon*, there are 6 pairs of *affarent branchial channels* and 6 pairs of *efferent branchial channels.* These channels are lacunar in nature. The afferent branchial channels run along the inner surface of the thoracic wall and reach the gills through the gill-roots. Here each channel opens into the tranverse connective. The first afferent channel takes the blood to the podobranch and two arthrobranches. Remaining five channels supply the blood to the five pleurobranches. The blood is oxygnated while passing through the gills and this blood is carried to the pericardium by efferent branchaial channels.

Course of blood circulation. It can be represented diagrammatically shown as below.

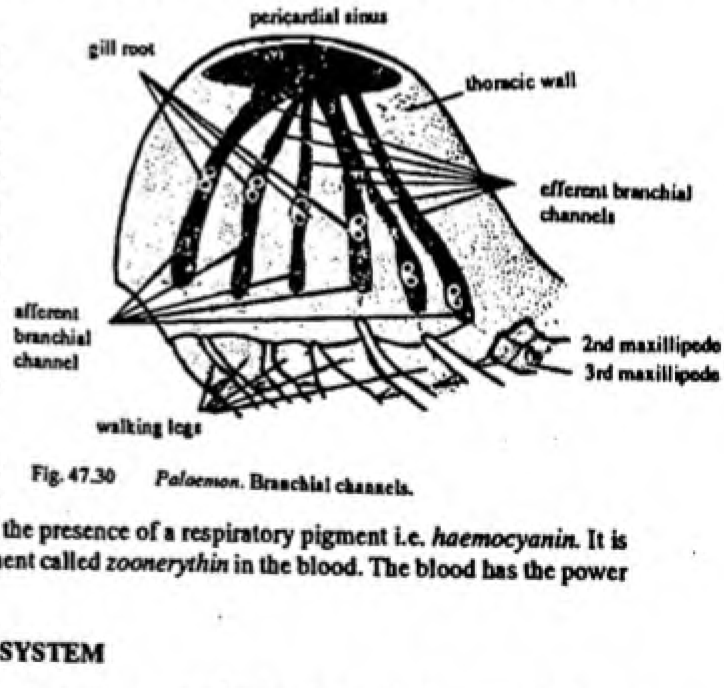


Fig. 47.30 *Palaemon*. Branchial channels.

6. **Blood.** The blood is a thin, watery, almost colourless liquid containing floating colourless *amoebocytes.* The colour of the blood is faintly bluish, when it is oxygenated. The colour is due to the presence of a respiratory pigment i.e. ***haemocyanin.*** It is a compound of copper and protein. There is also a lipochrome pigment called *zoonerythin* in the blood. The blood has the power of coagulation when it comes in contact with air.

EXCRETORY SYSTEM

The excretory system of adult *Palaemon* consists of a pair of *antennary* or *green glands* and a median sac termed a *renal sac.*

1. **Antennary or green glands.** The antennary glands are opaque white organs of the size of a pea-seed, are enclosed inside the coxae of each antenna. Each gland consists of 3 parts:

(i) End Sac

(ii) Labyrinth

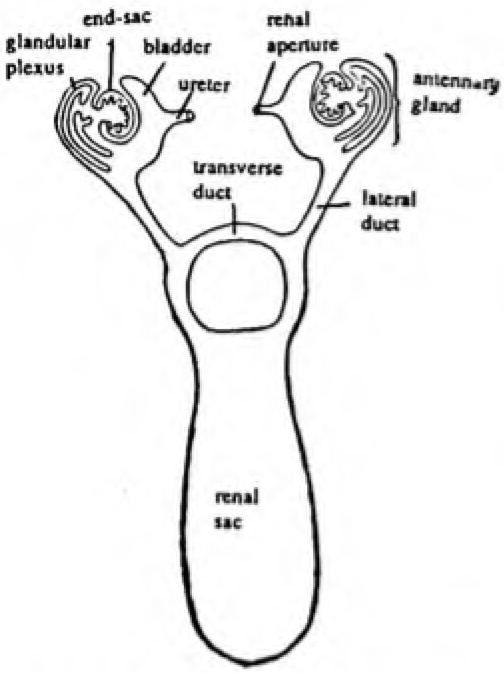


Fig. 47.31 *Palaemon.* Antennary gland.

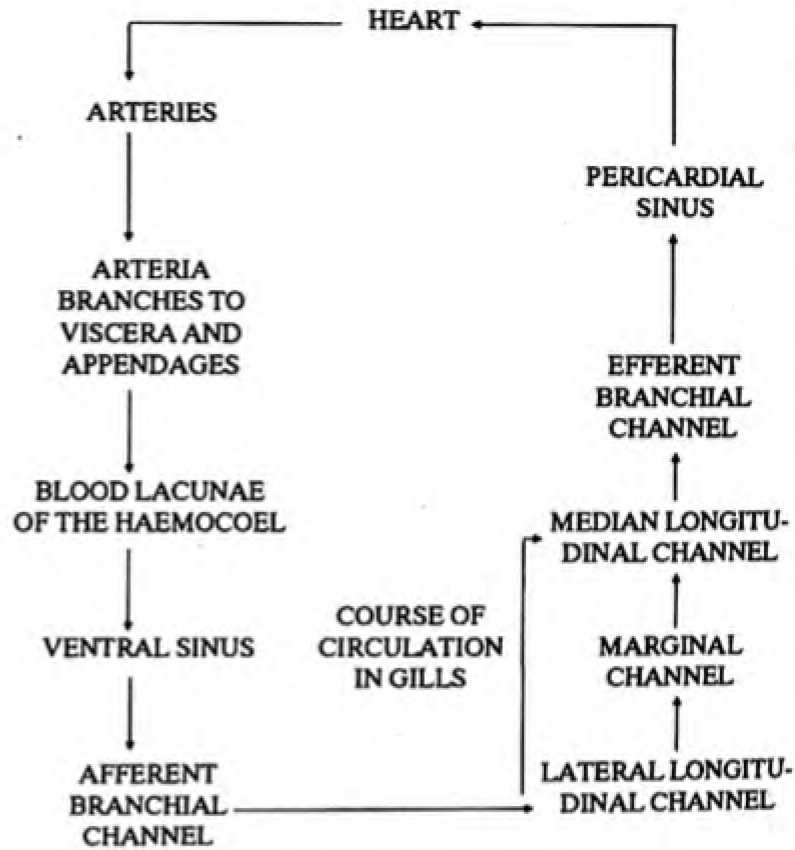


Chart Showing Course of Circulation in palaemon

(iii) Bladder

(i) *End sac.* It is a small bean-shaped structure lying in between the lebyrinth and bladder. Its wall is produced internally into folds and consists of two layers, outer thick layer of connective tissue with a number of small blood lacunae, and n inner thin layer of excretory epithelium. The cells are large with finely granular cytoplasm and rounded nuclei. The cavity of end-sac contains a large blood lacunae and communicates with the labyrinth by a single aperture.

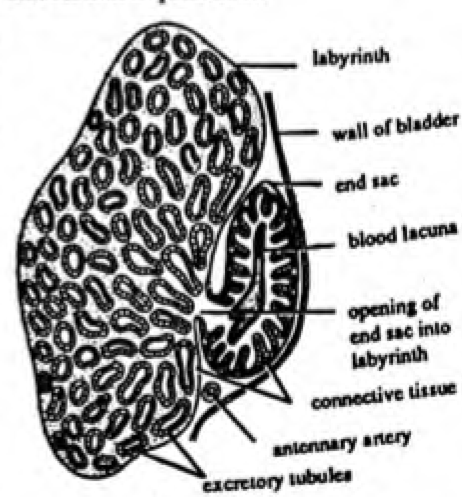


Fig. 47.32 *Palaemon.* Section of Antennary gland.

(ii) *Labyrinth.* The *labyrinth* or *glandular plexus* is very much larger in size then the end sac and lies on its outer side. It is a mass of highly convoluted and extensively branched excretory tubules. Which open, on one hand, into the end-sac by an aperture and on the other hand, into the bladder by several apertures.

The wall of each excretory tubule is formed of a single-layered excretory epithelium whose cells have large spherical nuclei and straited border.

(iii) *Bladder.* The urinary bladder is a thin-walled sac which consists of a single layer of excretory epithelial cells. It is situated on the inner side of the end-sac. Internally, its inner wall is continued as a short, excretory duct or *ureter*, which opens to the outside by a small renal or excretory aperture located on a papilla on the inner side of the coxal podomere of the antenna and in front of the labrum.

From the bladder, a narrow *laternal duct* runs posteriorly along the oesophagus. The lateral ducts of both the sides are joined by a transverse connective. These lateral ducts open into an elongated *renal or nephroperitoneal sac.*

2. **Renal sac or nephro-peritoneal sac.** It is a large median sac lying just beneath the dorsal shield. It covers the entire

cardiac stomach and reaches the gonads posteriorly. Anteriosly it communicates with bladder of each side by the lateral duct. The wall of renal sac is made up of a single layer of flatenned excretory epithelial cells.

Physiology of excretion. The antennary glands perform two functions, excretion and osmoregulation. These glands are richly supplied with blood so that by ultrafilteration, the water and dissolved substances are passed into the end sac. The filterate passes into the labyrinths. Where selective reabsorption takes place. The useful substances are pass back into the blood. The remaining fluid, better to say the *urine*, flows into the bladders and the renal apertures. The urine contains mainly ammonium compounds, some urea and amino acids.

Osmoregulation. *Palaemon* is a fresh water crustacean so that due to higher salt concentration of body the surrounding water continually diffuses into the blood through highly permeable gills. Excessive water is eleminated along with nitrogenous wastes that is why the urine of prawn is hypotonic.

Integument. The integument is also regarded as an organ of excretion in young stages. The nitrogenous wastes are deposited over the integument, which is cast off now and then during ecdysis.

NERVOUS SYSTEM

The nervous system of prawn is similar to that of earthworm in many respects. It consists of:

1. Central Nervous System

2. Peripheral Nervous System

3. Autonomic Nervous System.

1. **Central Nervous System.** The central nervous system includes a pair of cerebral ganglia, a pair of circum-oesophageal commissures and a double ventral ganglionated nerve cord.

   (i) *Cerebral or supraoesophageal ganglia.* It is a bilobed structure situated at the base of rostrum in front of the oesophagus. It consists of three pairs of fused ganglia, as it appears from the three pairs of nerves originating from it.

   (ii) *Circum-oesophageal commissure.* There are two stout nerves, which arise from the posterior end of brain and run backwards and downwards around the oesophagus. It unites ventrally with the sub-oesophageal ganglia which form the indistinguishable anterior part of the ventral thoracic ganglionic mass. Each commissure bears a small *commissural ganglion* near its anterior end, and gives off small nerve to the mandible of its side. The two circum-oesophageal commissures are connected with each other by a slender transverse commissure near the posterior end.

   (iii) *Ventral nerve cord.* It lies in the mid-ventral line of the body just above the sternal plates. The ventral nerve cord is actually double but due to fusion it has lost its double nature. It bears 17 pairs of ganglia. First eleven pairs of ganglia belong to cephalothoracic region. Thesae 11 pairs of ganglia are fused to from a single, large, oval mass called the *cephalothoracic* ganglionic mass. It is perforated by the sternal artery near its hind end. The posterior 6 pairs of ganglia of the nerve cord belong to the abdomen. The last abdominal ganglion is larger than others due to having several post-abdominal ganglia fused with it.

2. **Peripheral Nervous System.** It is formed by the paired nerves which arise from the various parts of central nervous system.

   (A) Five pairs of nerves arise from brain are:

   (i) *Antennulary nerves*: A pair of antennulary nerves arise from below the origin of optic nerves. Each nerve enters the antennule of its side into which it sends a statocystic branch to statocyst.

   (ii) *Optic nerves.* A pair of stout optic nerves arise from the doral surface of the brain, one on each side, and supply the eye-stalks.

   (iii) *Opthalmic nerves*: A pair of opthalmic nerves arise from the brain, one on each side, and supply the ocular muscles in the eye-stalks.

   (iv) *Antennary nerves.* A pair of stout antennary nerves originate from the ventral surface of the brain. Each nerve divides

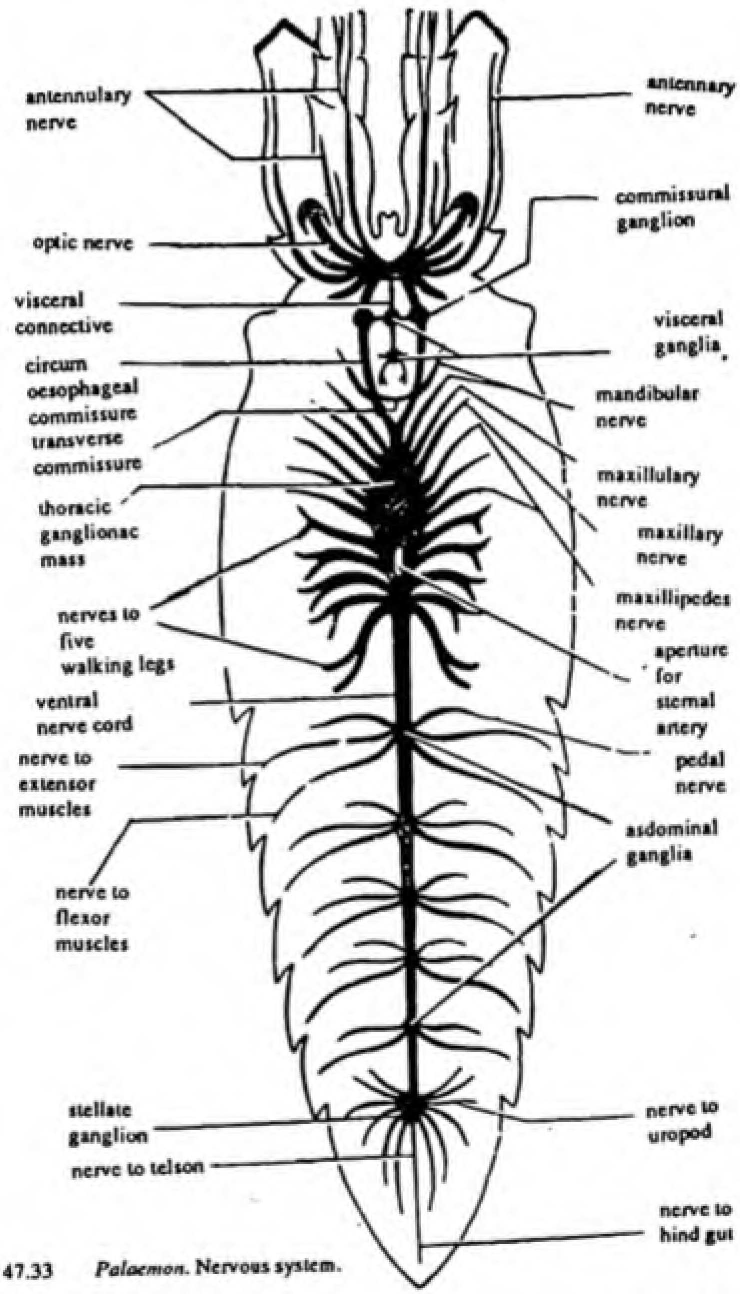


Fig. 47.33 *Palaemon*. Nervous system.

into two branches, the outer innervating the squama and the inner innervating the feeler of antenna.

(v) *Tegumental nerves.* A pair of slender tegumental nerves arise just behind the origin of antennary nerves. These nerves innervate the labrum.

(B) *Mandibular nerve.* It arises from the outer side of each circum-oesophageal connective and supplies the mandible of its side.

(C) *Nerves from cephalothoracic ganglionic mass.* 11 pairs of nerves are given out from the mass.

(a) *Mandibular nerves* for mandibles.

(b) *Maxillulry nerves* for maxillulae.

(c) *Maxillipede nerves.* There are three pairs of maxillipede nerves which supply to maxillipedes.

(d) *Peraeopod nerves.* These are 5 pairs in number and supplying to the walking legs.

(D) *Nerves from abdominal ganglia.* Each of the first four abdominal ganglia gives off three pairs of nerves in each segment.

(a) *Pedal nerves.* A pair of pedal nerves to pleopods

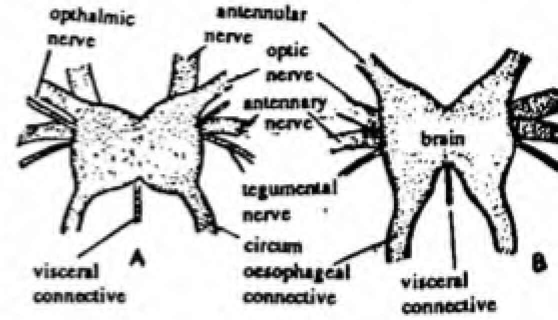


Fig. 47.34 *Palaemon.* Brain A—Dorsal view, B—Ventral view.

(b) A pair of nerves to the extensor muscles.

(c) A pair of nerves to the flexor muscles of the succeeding segment.

(d) The vth abdominal ganglion gives off 2 pairs of nerves, the nerves for the flexor muscles being absent.

(E) The Vth abdominal ganglion sends two pairs of nerves to the flexor muscles of sixth segment, two pairs of nerves to the uropods and two pairs of nerves to telson.

3. **Autonomic Nervous System.** The autonomic nervous system comprises a few small ganglia and nerves. A small nerve arising from the mid-posterior part of the brain, bears two *visceral oesophageal ganglion*, lying one behind the other. The first ganglion is jointed with the two *commissural ganglia* by a pair of connectives. The 2nd ganglion gives off two pairs of nerves to the walls of the oesophagus and cardiac-stomach.

ENDOCRINE SYSTEM

The endocrine system comprises a group of neurosecretory cells in each eye-stalk. These cells secrete several hormones into the *sinus gland* lying adjacent to them. From sinus gland, hormone is poured in the blood. These hormones are believed to regulate - colouration of body and compound eyes; deposition of lime salts in the exoskeleton and moulting. Moulting is controlled by two hormons moulting inhibiting hormone is secreted by X-organs in the eyestalks and moulting accelerating hormone by the Y-organ present beneath the adductor muscle of mandible.

SENSE ORGANS

The sense organs of *Palaemon* are:

1. Statocyst.
2. Olfactory setae
3. Tectile setae
4. Compound eyes.

1. **Statocysts.** The statocysts lie attached to the dorsal wall of the precoxa of each antennule and open through apertures on the dorsal concave surface. Each aperture is covered by a fold of skin. A statocyst is a subspherical cuticular sac about 1-1.5 mm wide. Each statocyst is supplied by the statocystic branch of antennulary nerve.

The cavity of the capsule possesses a heap of sand particles lined by a number of delicate elongated statocystic setae. Each seta consists of a swollen *base* and a long *shaft* which is half bent upon itself and covered with fine bristles. The base movably articulates with the wall of the sac

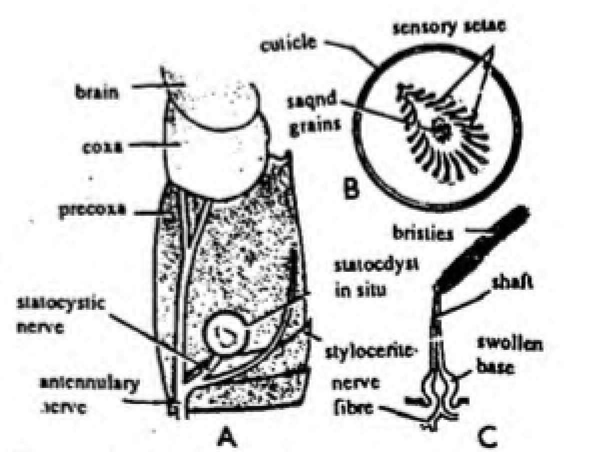


Fig. 47.35 *Palaemon.* A—Statocyst in situ, B—T.S., C—A single receptor.

by means of an arthrodial membrane and receives a fine branch from the statocystic nerve.

The statocysts are the organs of orientation and equilibrium. In the normal swimming position, the sand grains lie on the floor of the statocyst under the influence of the force of gravity. When the body of a swimming prawn gets tilted to one side it causes the displacement of sand particles in the same direction. This presses the sensory setae and stimulates them. The stimulated setae transmit this feeling to the brain and the prawn knows about its position and balances itself accordingly.

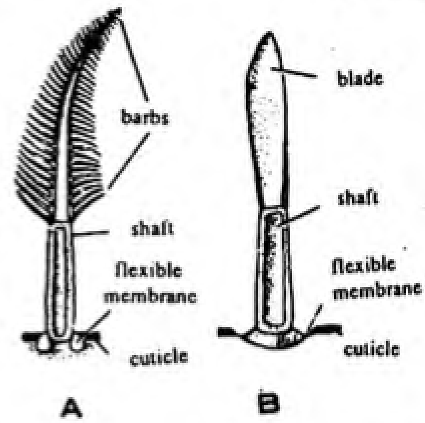


Fig. 47.36 *Palaemon*. A—Textile seta, B—Olfactory seta.

2. **Olfactory setae.** These are also known as aesthetases, occur on the middle small feeler of each antennule. Each setae consist of a basal segment or *shaft* and is attached segment of *blade*. Shaft is hollow and is attached to the integument while the later (blade) is free and bluntly rounded and is covered with a thin membrane. Small nerve fibres from the antennulary nerve supply these setae.

3. **Tactile setae.** These are situated on the elongated feeler of the antennae and other parts of the body, especially on the appendages. Each seta consists of a swollen base or *shaft* and a distal segment or *blade* with its central axis. The blade is tapering and slightly inclind distally and has two rows of barbs. The tactile setae are sensitive both to the surface as well as water current but get stimulates only when moved.

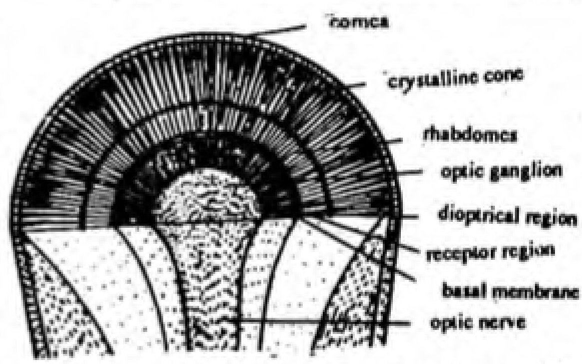


Fig. 47.37 *Palaemon*. L.S. of compound eye (diagrammetic).

4. **Compound eyes.** There is a pair of compound eyes, which are black and hemi-spherical. Each eye is situated at the base of short, movable and two jointed stalk. Each eye is contained in an orbital notch of the rostrum. Each eye is actually a composite structure being composed of a large number of visual units called as *ommatidia*. There are about 2500 such ommatidia in a compound eye. The surface of the eye is roughly hemi-spherical and is divided into a large number of small square facets. Each facet corresponds to a single ommatidium. All the ommatidia are similar, displayed radially, lying side by side and separated by a dark pigment cells. Each ommatidium consists of following parts:

(i) *Cornea.* The eye is protected externally by a transparent covering of cuticle known as cornea. It is distinguished into facets like those of graph paper.

(ii) *Corneagen cells.* These are flat one pair and of epidermal in origin. They secrete a new corneal layer after ecdysis.

(iii) *Cone cells.* Beneath the corneagen cells lie four elongated cone cells or *vitrellae*, which constitute a transparent, homogenous *crystelline cone.* The inner ends of cone cells are long and tapering.

This part of the eye from the cornea to the posterior end of the cone cells is called *dioptrical region* as it is concerned with the focusing of the light on the underlying region known as *receptor region.*

(iv) *Rhabdome.* The inner ends of cone cells lie upon an elongated, spidle-shaped, transversely striated structure known as rhabdome. It is secreted and surrounded by a group of seven elongated *retinal cells.* The inner end of the rhabdome are supported by a basal membrane beyond which they are continuous with the nerve fibres. The rhabdome and retinal cells from the *receptor region.*

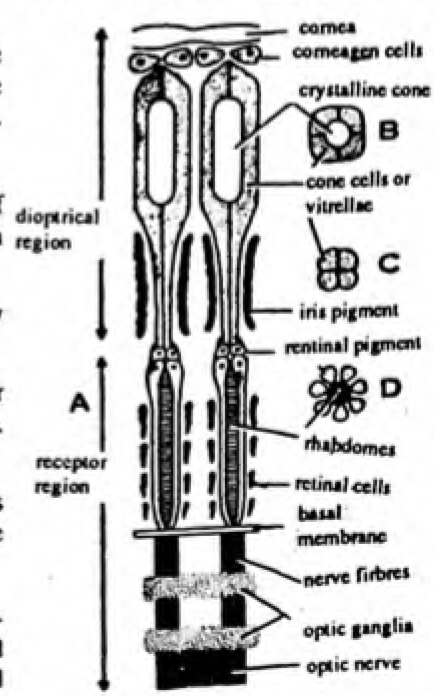


Fig. 47.38 *Palaemon*. (See figure for Caption).

(v) *Nerve fibres.* The ommatidia are innervated by nerve fibres of the optic ganglion.

Each ommatidium is ensheathed by densely pigmented cells which optically separate from the adjacent ommatidia. There are two sets of these pigmented cells: the *iris pigmented cells* forming the *iris sheath*, round the dioptric region and the *retinal pigmented cells* that form the *retinal sheath* round the receptive region.

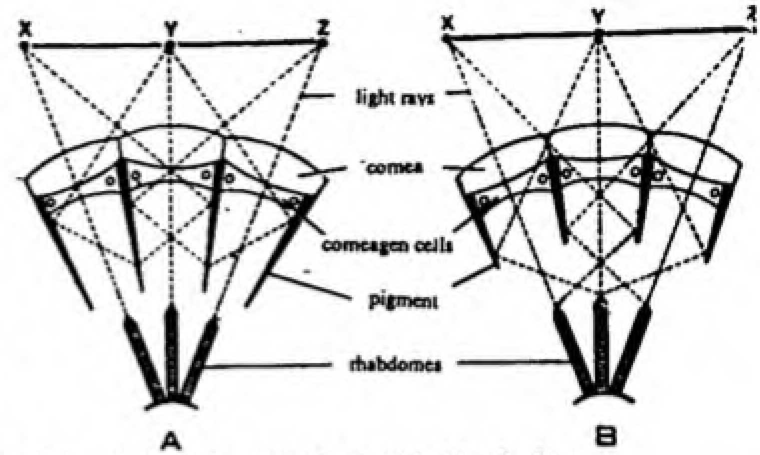


Fig. 47.39 *Palaemon.* A—Apposition or masaic vision, B—Superposition image.

Working of the eyes. The eye of prawn is so constricted that while it can swiftly spot out moving objects and is an efficient photoreceptive organ, it can neither focus properly nor can form a good clear image. Mounted on a movable stalk, it can move on the head and gives the animal almost 360° vision. Each ommatidium of the compound eye produces a separate image of an object present just infront of it. Therefore, the image formed of an object by this eye consists of several pieces contributed by many adjacent ommatidia just like a mosaic art net. That is why it is called a *mosiac vision.* The nature of the image depends upon the intensity of light.

(a) *Apposition Image.* In bright light the pigment cells spread in such a way that they completely separate optically one ommatidium from adjacent. No light can pass through the chamber walls from one ommatidium to the other. In this condition the rays of light, which strike the cornea obliquely are absorbed by the pigment cells without producing a visual effect. Only those rays of light, which pass directly through the centre of cornea, can traval through the ommatidium and reach the rhabdome to from an image of a part of object. As a result the complete image formed is a mosaic of several components places in juxtaposition. Such as image is called *apposition image.*

(b) *Super Position Image.* In the weak light, the pigment cells migrate partly towards the outer and partly towards the basal ends of the ommatidia. When this is the condition, even the oblique rays of the source of light are capable of forming a point of image, after passing through a number of ommatidia. Thus, a combined image is thrown on the retinular layer. In this way, an erect superposition image is formed as the rays refracted by several crystalline cones are superposed on the focus of retina. The superposition image is less distinct in detail than the apposition image, but it is more sensitive to weak intensities of light.

REPRODUCTIVE SYSTEM

The sexes are separate and there is a well marked sexual dimorphism. The males and females differ in several respects.

1. The males are larger than females.
2. Males have thoracic legs more closely arranged than in the females.
3. Males have narrower abdomens then those of the females.
4. In males the 2nd pair of chelate legs are longer and have a thicker covering of setae and spines.
5. Males have appendix masculina arising from the appendix interna of each pleopod of the second pair.
6. In males, the epimeres of abdominal segments are smaller in size than in the females, where they are bigger in size for carrying eggs.
7. In males, the paired genital and thoracic openings are situated on the arthrodial membrane between the 5th pair of the walking legs covered by a flap of integument, while, in the females, the generative apertures are situated on the coxae of 3rd pair of the walking legs.

Male Reproductive Organs. The male reproductive system comprises:

1. Testes.

2. Vasa deferentia

3. Vesicula seminalis.

1. *Testes.* The testes are median dorsal structure situated in the posterior part of the thorax above the hepatopancreas and below the pericardium. They extend anteriorly upto the renal sac and posteriorly upto the first abdominal segment. These are soft white structures which are fused anteriorly to from a single lobe, while at the posterior end these remain in close contact. The two testes enclose a central space or gap which gives way to the *cardiopyloric strand* connecting the heart to the cardiac stomach.

Each testis consists of a large number of coiled, hollow thin walled *seminiferous tubules* buried in connective tissue. The cavity of each tubule is lines by a single layer of *epithelium*, the cells of which undergo *spermatogenesis* to form the *spermatozoa*. A mature sperm consists of a rounded cytoplasmic body, containing a large, dark crescentic nucleus, and a tail-like blunt process.

2. *Vasa deferentia.* From the outer surface of the posterior end of each testis arises a very long and narrow tube, the *vas deferens*. It is differentiated into two parts: the proximal highly convoluted part which emerges out of the testis and the distal straight part which runs vertically downwards between the abdominal flexor muscles and the thoracic wall. Each runs inwards to open into the vasicula seminalis.

3. *Seminal vesicles.* The distal part of each vas deferens enlarges to form a seminal vesicle or *vesicula seminalis* near the coxa of 5th walking leg. It is club shaped structure which opens to the outside through the male genital pore on the inner surface of coxa of 5th leg. The male genital pore is covered by a small flap-like piece of skin. The vesicula seminalis stores the sperms.

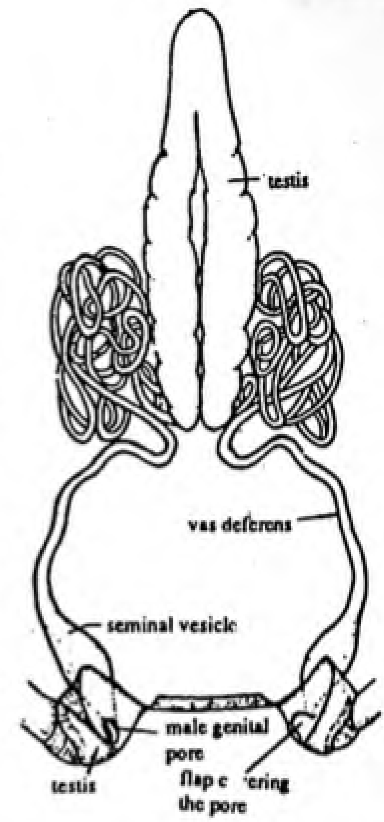


Fig. 47.40 *Palaemon*. Male reproductive system.

Female Reproductive System. The female reproductive system comprises following organs:

1. Ovaries

2. Oviducts.

1. *Ovaries.* A pair of ovaries which are compact and sickle-shaped bodies touching each other at both the ends but leaving a gap in the middle for the passage of the cardiopyloric strand. The shape and size of the ovaries vary with age and the season of the year. Each ovary is enclosed within a membranous capsule and is made of numerous radial rows of *ova* in various stages of development. The immature ova lie towards the centre while the mature ova towards the surface of the ovary. The latter are large nucleated cells with planty of yolk material.

2. *Oviducts.* From the middle of the outer surface of each ovary arises a short thin-walled tube known as *oviduct*. Its anterior end is broad and forms the *oviducal funnel*. It lies opposed to the surface of ovary. The oviduct runs vertically downwards to open to the exterior by *female genital pore*. It is situated on the inner side of coxa of 3rd walking leg.

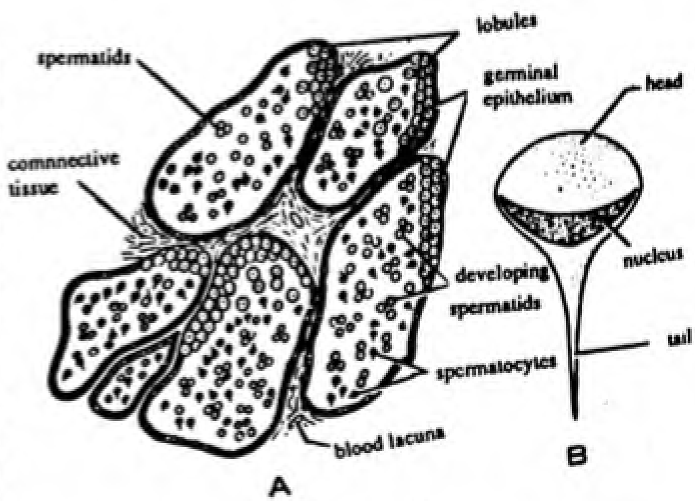


Fig. 47.41 *Palaemon*. A—T.S. testis, B—A sperm.

Fertilization

Breeding season in *Palaemon* is from May to July. During the season, the females carry eggs attached to their pleopods. Except in breeding season, the females are found without eggs. Fertilization is external. When ova are laid, they are attached to the setae on the pleopods with the help of a sticky secretion of glands situated both on the appendages and on the body segments. The male, later on, deposits sperms near the genital openings, where fertilization takes place. It is not yet known that how male deposits spermatophores.

Development

In *Palaemon lamarrei, P. malcolmsonii* etc. The development is direct i.e. without larval stage. However, in other prawns (*Penaeus, Lacifer*) the development is indirect i.e. with larval stages.

The cleavage is *superficial.* The nucleus of fertilized egg, lying in the centre, divides and redivide forming a number of nuclei. These nuclei are later on enclosed by masses of protoplsm, but areas of the separate cells do not become marked off by furrows cutting right through the egg. As a result of segmentation, a blastoderm is formed, which appears at first on the ventral side of the egg. Its formation begins at one point on the surface and proceeds gradually from this point, which always represents the future ventral side of the egg. Gastrulation starts from the posterior end of the ventral side which is marked by the first formation of the blastoderm.

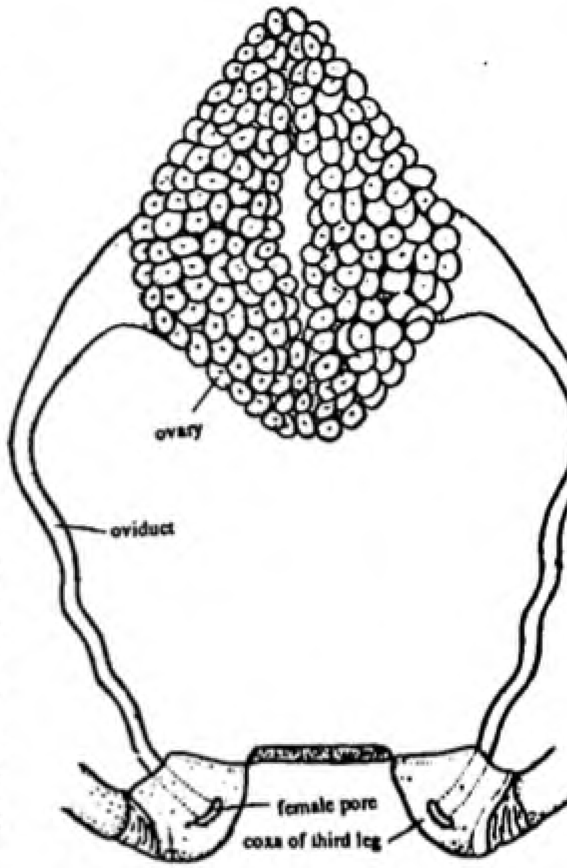


Fig. 47.42 *Palaemon*. Female reproductive system.

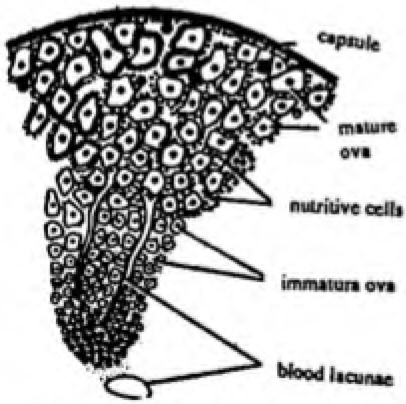


Fig. 47.43 *Palaemon*. T.S. of ovary.

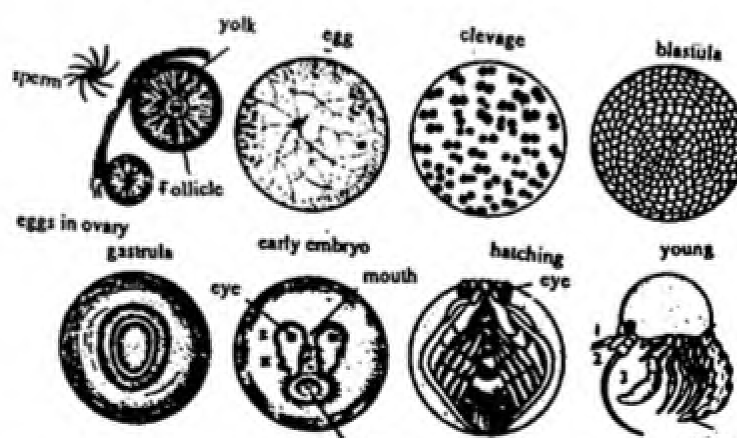


Fig. 47.44 *Palaemon*. Showing development.

Gastrulation

A small invagination develops at a time when the blastopore is not completely formed. This invagination marks the first step towards gastrulation and small *archenteron* is formed with its opening, the *blastopore.* When the blastopore closes, the cells of the endodermal vesicles lose their epithelial nature. From the lateral walls of the endoderm vesicle arise elements which form

the mesoderm at a later stage. Endoderm is formed by the cells, which arise from the floor of endodermal vesicle and pass on to the yolk and multiply therein. Each of these endodermal cells swallows the surrounding food yolk, with the result the yolk mass breaks into smaller spheres. Afterwards the midgut is formed by the inter-penetration of the food yolk by the cells of gastrula. Fore-gut and hind-gut also arise by ectodermal invagination forming stomodaeum and proctodaeum. Both reach the midgut and finally fuse.

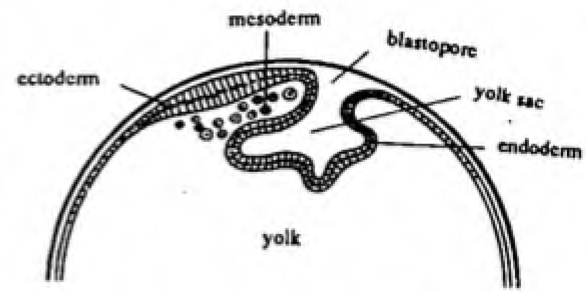


Fig. 47.45 *Palaemon*. V.S. of early gastrula.

When the mesoderm appears for the first time, it consists of a mass of cells near the point of origin. These cells multiply rapidly and spread out apparently in an irregular manner between the ectoderm and the food yolk.

The ectoderm gives rise to the external integument and an internal skeleton. Nervous system develops from ectodermal thickening. Vascular system is developed from the mesenchyme. Growth of the main parts of the embryo in size, during which the entire yolk is consumed, results in a small individual which is similar to adult except size. After several moults the adult is formed.

POWER OF REGENERATION

Prawns and certain other crustaceans like lobsters, crabs, cryfishes etc., have a power of regeneration which is greater in young stages but very slow in adults for example, if the tip of eye is removed, normal regeneration takes place. If the entire eye stalk along with optic nerve is removed, an antenna like structure is formed. Such type of regeneration in which normal organ is not developed, is called *heteromorphosis*.

Crustaceans have the power of autotomy. If a thoracic leg is broken in some mishap, its distal segments are spontaneously thrown off to feed the enemy.

48

PRAWN FISHERY

Prawn, a crustacean, commercially known as shrimps, is considered by most people a fish. Due to its nice taste, it is supposed to be a cherished delicacy to serve as food throughout the world. Prawn fishery implies capture of prawns from their natural resources and also their culture. It has sufficiently advanced in India. There are different varieties of prawn inhibiting sea, estuaries and fresh waters. Production of prawn in India is second to U.S.A. and it is also important because it is an important item of our export and the annual foreign exchange returns from 70-80 crores of rupees.

TYPES OF PRAWN

As mentioned earlier that prawn inhibits all sorts of water i.e. marine, estuaries and fresh water of temperate and tropical countries. Prawn fishing in marine water is mainly restricted to west coast. Kerala and Bombay coasts are the chief centres for the production of marine prawns. Among marine prawn, the older specimens line upto 30 metres deep and the younger one up to 18 meters deep. The important species of prawns found in coastal region and *Penaeus monodon* (the giant tiger prawn), *P. indicus* (Indian prawn), *P. mergniensis* (banana prawn), *Metapenaeus dobsoni* (yellow prawn), *M. affinis, M. monoceros* etc. are very common. Among these *P. indicus* occurs most commonly and constitute the bulk of production. It measures upto 20 cm in length. The largest being *P. monodon*, measuring 30 cm in length but it is not very common. *Metapenaeus dobsoni, M. affinis* and *M. monoceros* are most suitable species to be cultured in India, Pakistan, Philippines, Malaysia, Indonesia etc.

The species of estuaries prawns are the same which occur in marine water except *Penaeus stylifera*. Which is exclusively marine. The important areas of prawn production in estuaries are southern half of Kerala Coast. Several lakes like Chilka, Colliar, Ennore, Pulicat etc. are also some areas of prawn production.

The exclusive freshwater species in *Macroboachium sabriculs*, where as *Metapenaeus monoceros* and *Penaeus monodon* are freshwater as well as marine, for freshwater culture, giant fresh water prawns. *Macrobrachium resenberghi, M. malcolmsoni* are best suited.

FISHING

The method employed for fishing prawns are somewhat similar to that of fishes. Fresh water prawn are caught round the year and so also the marine prawn but there are certain peak seasons. Along west coast, it is November to May, offshore fishing is most profitable from July to October. Along east coast from December to August. Various types of nests are used for prawn fishing, amongst which the commonest type used is boat siene. In estuaries, a peculiar type of conical net, supported by a pair of stakes is being used. Other types of nests like wall net, drag net etc. are also used for this purpose.

PRAWN CULTURE OR FARMING

There are two methods for prawn culture: (i) The old and conservative process. Commonly called as *traditional method* is widely used in India. The ponds situated near the estuarine and brackish water are selected for the purpose. The ponds remain connected with the outer main tidal stream by sluice gates. These are kept open during high tide when larvae get in. During low tide they are open but the larvae are prevented from escaping. After growing upto a marketable size, the field water is filtered and the prawns are collected. During their growth the larvae are provided with natural diet. However, in Philippines, instead of a natural diet, artificial diet is provided. Another method of collecting is to set up bag nets or bamboo traps near the sluice gates. During night electric bulbs which attract shrimps are also used for quick trapping.

(ii) Philippines, Japan, U.S.A. etc. are employing modern technique for culturing. This method is called *intensive prawn culture*. It includes the rearing of post larval stages of prawn and its breeding and spawning at desired places by providing the artificial environment. Matured males and females are kept in small concrete tanks where temperature and oxygen concentration are maintained artifically. After spawning the adults are removed. The early larval stages are fed on phytoplanktons like diatomes where as the post-larval stages are provided brine shrimp larvae, worms etc. as food. On attaining the desirable size, the larvae are transferred to the production tanks. These tanks have two openings which are connected to the main stream of water through water pipes with the help of hydraulic pumps, the water in poud is made to circulate. This method gives much more production than traditional method.

In India intensive prawn culture is in experimental stage. Experiments performed by Kerala state at Narakkal, Vypean Island have shown an annual production of 363 kilogramms per acre.

PRESERVATION AND PROCESSING

Since the prawn is an important article for export, their preservation and processing is necessary. If distance is short, they are packed between layers of ice either entirely or after removing cephalothorax. For long time preservation two methods are employed.

(i) Total drying

(ii) Semi drying

(i) In total drying, the entire prawn are dryed in tube sun for several days. In some places, they are boiled are thrased to remove the shell. Now they are packed for marketing.

(ii) In semidrying techniques the prawns are boiled in 6% brine for just two minutes. After that the shell is removed and the prawns are dipped in saturated salt solution for half an hour. The process is followed by drying in the sun, but the drying is stopped before the flesh gets too hard. Such semidried prawns when socked in water give the original taste after months.

Besides other methods like chilling and freezing, pulp making, pickling, smoking and canning are also employed.

PRAWN MANURE

It includes semi-dried prawns and heads, tails and chitinious shells of prawns. It contains 5-6% nitrogen and phosphates and chitinous body shells if dried and powdered, provide prawn meal a protein rich poultry feed.

POLLUTION

Prawn fishery is affected by pesticides, effluents, metals and oils.

49

PERIPLANETA AMERICANA

The cockroach is a familar type of the class Insecta belonging to order Blattaria. These are very ancient insects and are found practically all over the world except the polar regions. There are about 2600 species of cockroaches of which the common species in India are *Periplaneta americana, Periplaneta australasiae, Blatta orientalis* and *Blatta germanica. Periplaneta americana* was originally designated as *Blatta orientalis* by *Linnaeus* (1958), later changed to *Blatta kakeralac* by *De Geer* (1973) and finally the present name was given by *Burmeister* (1838).

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Blattaria
Family	-	Blattidae
Genus	-	*Periplaneta*
Species	-	*americana*

HABITS AND HABITAT

They are generally found in warm damp places particularly in kitchens, cupboards, hotels, drains, ships, trains and even sewers. Cockroaches eat everthing fit for human consumption, besides they will eat leather, paper, cloath and wool, thus they are omnivorous. Sometimes when the food is not available they turn cannibal and eat each other. Cockroach is nocturnal i.e. it comes out to feed at night. Cockroaches are cursorial i.e. run very fast though they can fly also. The eggs are laid in oothecae. The young ones hatching from oothecae resemble the adult in mode of life except that they are smaller in size.

EXTERNAL CHARACTERS

Shape and Size. The body of cockroach is narrow elongated, bilaterally symmmetrical and dorsoventrally flatenned. It is about 4 cm in length and one cm wide.

Colouration. The colour is reddish brown. The tergum of the first thoracic segment bears two dark patches surrounded by a light brown margin.

Exoskeleton. The entire body is covered by a hard brown coloured chitinous exoskeleton. Each segment of the body has hardened plates called *sclerites* which are joined to each other by thin flexible *articular*

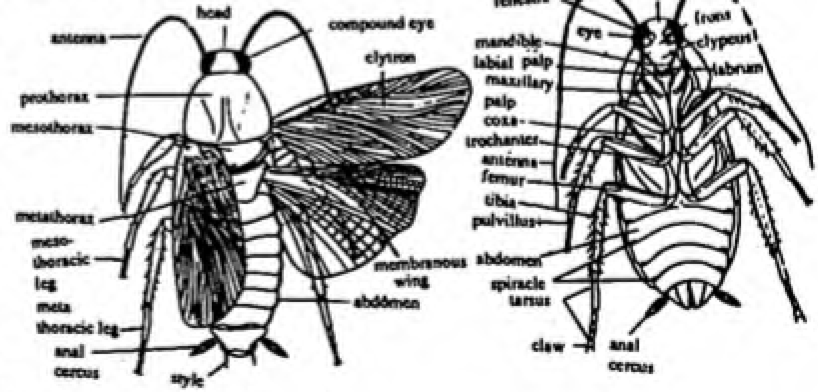


Fig. 49.1 *Periplaneta.* A—Dorsal view, B—Ventral view.

membranes.

Division of body. The body is divisible into three distinct region:

1. Head

2. Thorax

3. Abdomen

1. ***Head.*** The head comprises the anterior body region of cockroach. It is sclerotized capsule formed by the fusion of several sclerites, often distinctly seen in the embryo. It lies at right angle to the longitudinal axis of body and is highly movable in all direction due to a flexible neck.

The head bears large compound eyes which are broad dorsally. A dark sclerite covers the top of the head and extends downwards between the eyes. It is called *vertex*. In the nymph the vertex is divided into two *epicranial plates* by an inverted Y shaped *epicranial suture*. During moulting of the numph, the head capsule splits at the epicranial suture, and the epicranial suture disappears in adult. The unpaired triangular plate, lying between the arms of the epicranial suture is the *frons*. Below the frons is *clypeus* and *labrum*. Covering the sides of the head and lying below the compound eyes are cheek sclerites or *genae*. In the angle between the eyes and antennae are two small pale coloured areas called *fenestrae*, which are undeveloped *ocelli*. At the back of the head is a large rectangular *occipital foramen* bordered by an arched sclerite, the *occiput*.

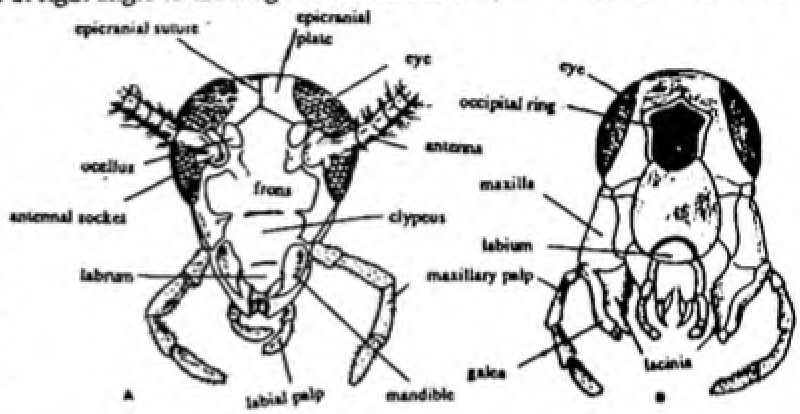


Fig. 49.2 *Periplaneta* Head A—Front view, B—Hinder view.

The head bears a number of appendages. The *antennae* are a pair of long, multi-jointed, thread-like, movable structures attached infront of the eyes. Each antenna articulates in membranous pit, the *antennal socket* and has three parts a basal large segment, the *scape*, a short second segment termed the *pedicel* and a long many jointed *flagellum*. The antennae are considered to be modification of the second head segment.

Mouth Parts. These are movably-articulated appendages surrounding the mouth. The mouth parts are *chewing* type. They include a *labrum*, a pair of *mandibles*, a pair of *maxillae*, a *labium* and *hypopharynx*.

(i) *Labrum.* It hangs downwards from the membranous posterior part of clypeus and is actually an appendage of 3rd segment. It forms the anterior wall of the preoral cavity and is called the upper lip. It bears on each side of its inner anterior surface a sclerite *torma* and two rows of gustatory setae.

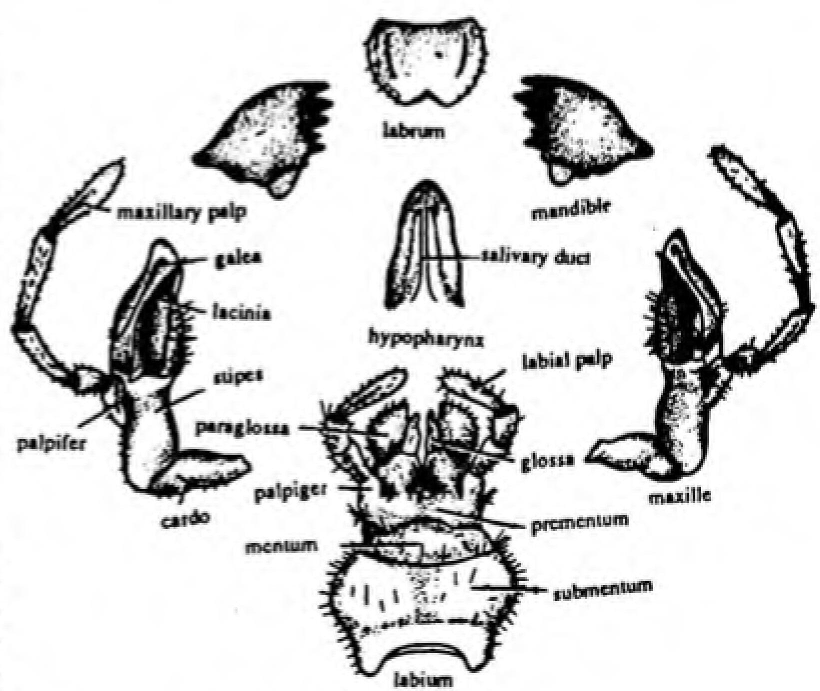


Fig. 49.3 *Periplaneta.* Mouth parts.

(ii) *Mandibles.* The mandibles articulate with the genae and lie on the sides of mouth just behind the labrum. These are the appendages of 4th segment and have ball and socket attachment with the head. These are heavily sclerotised and bear 3 - teeth like structure and a small serrated molar area. The upper inner margin bears a membranous lobe, the *prostheca* from which sensory hairs arise. Each mandible is worked by four muscles.

(iii) *Maxillae.* Two maxillae lie below the mandibles. They are regarded the appendages of 5th segment. Each maxilla is biramous appendage consists of three parts: The basal *protopodite*, inner *endopodite* and outer *exopodite*. The protopodite is made of two joints proximal *cardo* and distal *stips*. The exopodite is a long structure arising from a small projection, the *palpifer*, on the outer side of the distal end of stipes. It is formed of 5 joints and known as *maxillary palp.* The endopodite is attached to the distal end of the stipes internal to maxillary palp. It is made up of two pieces, outer *galea* and inner *lacinia.* The lacinia bears bristles along the inner margin and ends in the two sharp claws. The maxillae hold food by the claws of lacinia and bring it to the mandibles for mastication. They are also used for cleaning of antennae, palps and front legs.

(iv) *Labium or second maxillae.* The labium lies behind the first pair of maxillae. It is formed by the fusion of second pair of maxillae along the middle line. The basal joint of the fused protopodites, is the *submentum*, the second is *mentum* and the third is *prementum.* The endopodite of labium are almost separate, and are together known as the *ligula.* Each half of ligula comprises two pieces the inner smaller *glossa* and outer *paraglossa.* The exopodites are also separate. They are called *labial palps.* Each labial palp arises from a short projection, the *palpiger*, of the premantum and consists of three joints. The labial palps bear sensory bristles. The labium takes no part in feeding, but the glossae and paraglossae together termed the *ligula* prevent the loss of food particles from the mandible thus acts as lower lip.

(v) *Hypopharynx.* It is the tongue or *lingua* which lies between the maxillae and labium inside the mouth cavity. The salivary duct opens at the base of the hypopharynx.

Neck. A narrow, elastic and a short neck joins the head with the thorax. Its exoskeleton is made up of chitinous plates called *cervical* plates. It is nearly extension of an articular membrane and not a segmental region of the body.

2. *Thorax.* The thorax consists of three segments (i) anterior *prothorax*, (ii) middle *mesothorax* and (iii) posterior *metathorax.* The exoskeleton of each segment consists of a *notum* or *tergum* on the dorsal side, a *sternum* on the ventral side and a *pleuron* on either lateral side. The tergum (pronotum) of the prothorax is the largest and projects forwards to conceal the neck and a part of head also. The mesotergum and metatergum are smaller and rectangular. The sclerites of each segment and also those of the adjacent segments are joined by thin, soft, flexible *arthrodial membranes* to permit movement.

Legs. Thorax bears three pairs of legs, one pair per segment. All the legs are similar in structure. They are called *prolegs, mesolegs* and *metalegs* on the basis of the segment which bears them. Each leg bears five segments:

(i) *Coxa* which is attached with the thorax between pleuron and sternum, forms a morable joint.

(ii) *Trochanter*, which is smaller than coxa, can move freely on it.

(iii) *Femur*, which is long and broad.

(iv) *Tibia*, which is long and of uniform thickness.

(v) *Tarsus*, which is the last segment of the leg. It is made up of 5 movable podomeres. The last podomere ending into two small-hooked *claws* is often called *pretarsus.* Between the claws, there is a delicate, hair-covered porous pad, the *pulvillus* or *arolium.* The tarsal segments bear many fine hairs, while at their lower edges are soft adhesive pads, the *plantulae.* The pads afford grip on the smooth and slippery surface where claws fail to hold on.

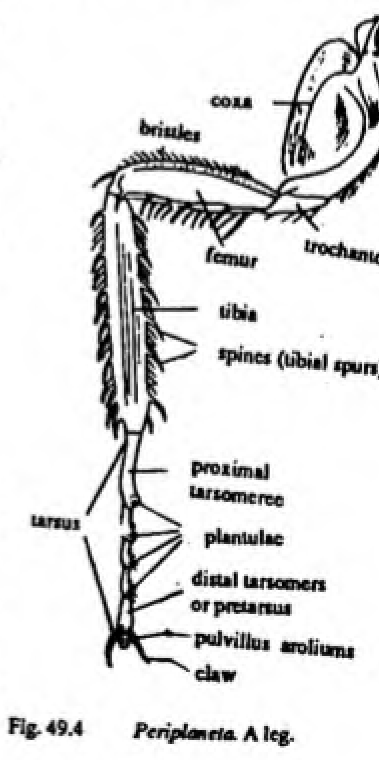


Fig. 49.4 *Periplaneta.* A leg.

Wings. Besides the legs, the thorax also bears two pairs of wings. According to their position, the wings are called the mesothoracic and metathoracic. The wings are formed as lateral extensions of the integument between the tergum and the pleuron near the anterior

end of the segment. The first pair of wings are heavily sclerotised and are known as *elytra* or *tegmina*, they are protective and cover the hind wings in a folded state, the left tegmen partly overlap the right. The second pair of wings are membranous and larger, they lie folded below the tegmina when at rest. Each wing has two thin membranous layers tubular and chitinous prolongations of the haemocoel between them known as *veins* or *nervures*. They are highly sclerotized and enclose small trachae and even nerve fibres.

The movements of each wing during flight are effected by two sets of muscular, the *direct* and the *indirect* muscles. The direct muscles are so called because they are inserted directly on the sclerites at the base of the wings. The indirect muscles are not inserted on the wings. One group of indirect muscle runs dorsally and longitudinally between the mesothorax and metathorax, the other group runs dorso-ventrally between the tergum and sternum.

3. ***Abdomen.*** The abdomen consists of 10 segments in adult but 11 segments in embryo. Typically, each segment has its own tergum and sternum. The 8th and 9th terga of female and only 9th tergum of male are largely covered by the 7th tergum. The 10th tergum projects backwards beyond the abdomen and is cleft into two lobes whereas all abdominal segments have their own terga, there are only nine sternal plates. First sternum is small but all others are well developed. In the female the 8th and 9th sterna are invaginated and completely concealed by the enlarged boat shaped 7th sternum. This large sternum encloses a big space called *oothecal chamber* or *gynovalvular chamber*, where ootheca is formed. In males the 8th and 9th sterna are concealed by 7th sternum but there is no such chamber, however, there are a pair of small, thin and unjointed *anal styles* projecting back from the 7th sternum. Anal styles are absent in female. Other paired outgrowths are called *anal cerci* arise from the 10th tergum. These cerci are 15 jointed, longer and thicker structures. These are present in both the sexes.

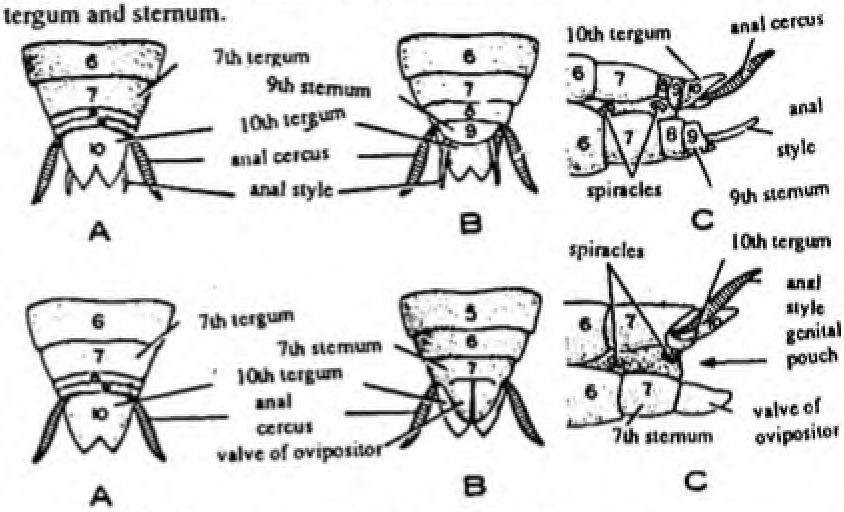


Fig. 49.5 *Periplaneta* Abdomen. Upper A, B, C—Male, lower, ABC—Female.

In male there are a group of chitinous hooks and plates near the end of the abdomen, these are the *gonapophyses* which help in copulation. Some chitinuous structures in the female have a similar position and form an *ovipositor*.

In the 10th segment just below the tergum is *anus* supported by a pair of *podical plates*. The *gonopore* is both the sexes occurs below the anus and is surrounded by gonapophyses.

Spiracles. There are 10 pairs of small slit-like apertures on the lateral sides of the body, called *spiracles*. Two pairs of these are larger and situated on the thorax, one between the pro- and mesothorax and other between meso - and methathorax. Rest of the 8 pairs are called abdominal spiracles present on the sides of abdominal segments 2-8, each being located between the two adjacent terga and two ajcacent sterna.

Stink glands. The intersegmental membrane between the 5th and 6th abdominal terga is depressed on either side to form a stink gland. These glands produce a secretion with a characteristic odour.

BODY WALL

The body wall has three distinct layers:

(i) Cuticle

(ii) Epidermis

(iii) Basement membrane.

(i) ***Cutile.*** It is the outermost layer and is differential into three regions: an outer *epicuticula*, middle *exocuticula* and inner *endocuticula*. The epicuticula has an outer layer of wax-like lipoid and an inner layer of hard protein, but the chitin is absent. It bears movable and fixed bristles. The exocuticle is a thick, laminated, flexible layer of chiton. It bears pigments and is sclerotized. It gives both rigidity and elasticity. The endocuticle is made up of protein and chiton arranges in horizontal lamellae. A few *pore canals* are present in exo-and endocuticle.

(ii) ***Epidermis or hypodermis.*** It comprises a single layer of columnar epithelial cells resting on the basement membrane. It secretes cuticle. The gland cells which secrete movable hair-like setae that project from the surface of cuticle, are present in epidermis.

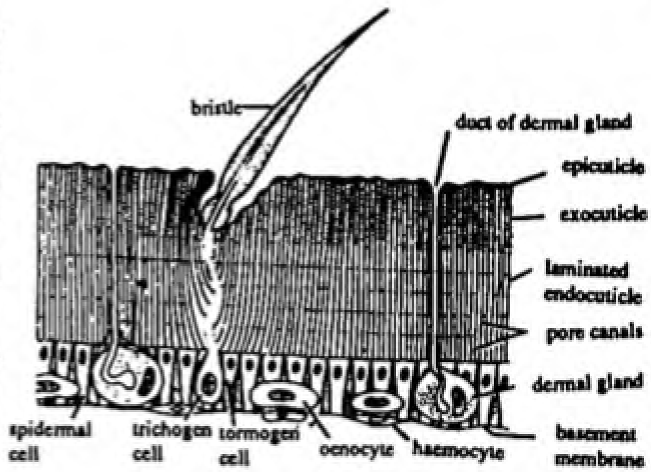


Fig. 49.6 *Periplaneta.* T.S. of body wall.

In adult cockroach large oval cells are present below the epidermal cells called *oenocytes*. The oenocytes probably secrete wax.

(iii) ***Basement membrane.*** The basement membrane is generally 0.5 micrometer or less in thickness and in electron microscope appears as a continuous, amorphous granular layer. It is composed of mucopolysaccharides.

ENDOSKELETON

The endoskeleton in cockroach is made up of chitin. The endoskeleton of head is known as *tentorium*. It lodges in the posterior part of the head. It consists of a chitinous plate with a small aperture in it. Three pairs of processes arise from this plate; *anterior arms* attached with clypeus and frons, *posterior arms* attached with the posterior part of the head and *dorsal arms* bent towards the antennae.

BODY CAVITY

The true coelom is reduced and is represented by the cavities of gonads. The body cavity is filled with blood and is called the *haemocoel*. Loose tissues known as fat bodies or corpora adiposa are found in the body cavity.

DIGESTIVE SYSTEM

The digestive system comprises the *alimentary canal* and *digestive glands* associated with it.

I. Alimentary Canal. The alimentary canal comprises three regions.

1. Foregut or Stomodaeum

2. Midgut or Mesenteron

3. Hindgut or Proctodaeum.

1. ***Stomodaeum.*** Its inner wall is made up of epithelial cells and lines with cuticle. The stomadaeum comprises: preoral cavity, pharynx, oesophagus, crop and gizzard.

(i) *Preoral cavity.* It is bounded anteriorly by the labrum and clypeus, posteriorly by labium and laterally by mandibles and maxillae. Inside the cavity the hypopharynx is present. It bears the opening of salivary duct. The mouth lies on the roof of the preoral cavity. The mouth leads into a tubular *pharynx*.

(ii) *Pharynx.* It is a vertical canal that rises up in the head capsule and passes over the tentorium, and then bends to open into the oesophagus near the occipital foramen.

(iii) *Oesophagus.* It is a narrow tube that is present in the neck and extends into thorax to open in the crop.

(iv) *Crop.* The crop is a large thin walled, pear-shaped sac extending well into the abdomen. It serves as a reservior for storing food. Its outer surface is covered by a network of tracheae. Its internal epithelial and cuticular lining is very much folded.

(v) *Gizzard or proventriculus.* The crop leads behind into a small, thick walled, muscular and cone shaped proventriculus. Anteriorly it bears an *armarium* and posteriorly a *stomodaeal valve.*

The armarium possesses internally six longitudinal folds that greatly reduce its lumen. These longitudinal folds alternate with six longitudinal grooves. The cuticular lining of each longitudinal fold forms (a) in the anterior part, a thick plate produced centrally into strong, sharp teeth and (b) in the posterior part, a *thin plate.* Behind each longitudinal fold the cuticular lining of the gizzard forms a soft cushion-like lobe, the *pad* or *pulvillus,* with long, backwardly directed hair. Behind the region of the pads the proventriculus extends into the lumen of the midgut as the stomodaeal valve. The latter folds back on itself, and is thus double-walled.

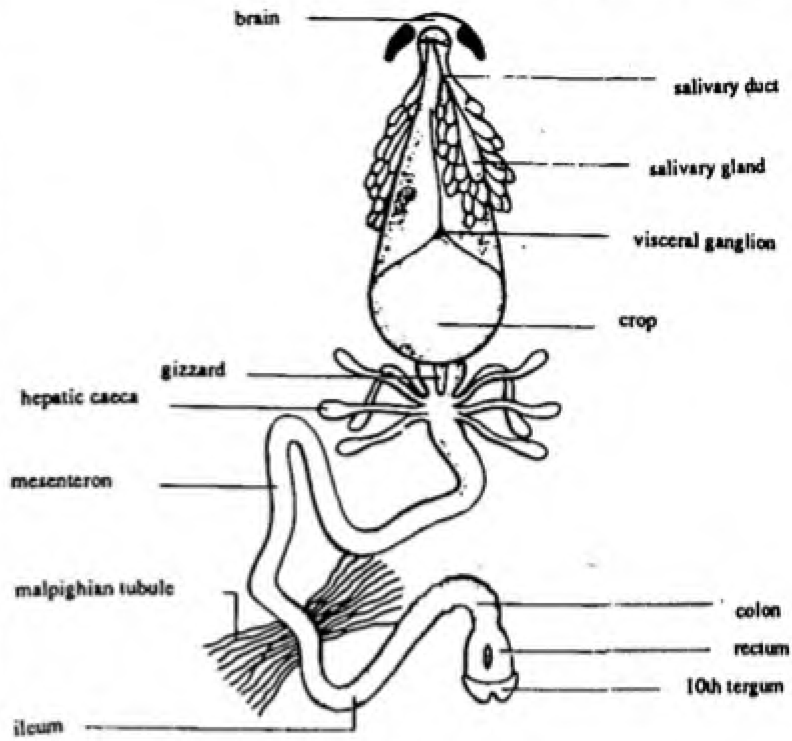


Fig. 49.7 *Periplaneta.* Alimentary canal.

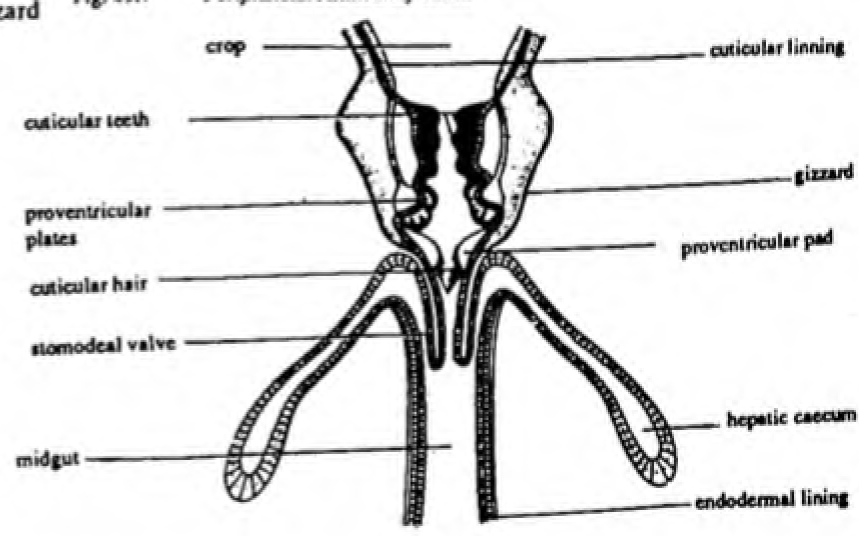


Fig. 49.8 *Periplaneta.* Section through gizzard and mesenterion.

2. ***Mesenteron.*** Behind the gizzard is a tubular mesenteron or midgut lined with endodermal cells, it performs the tasks of completing the digestive process and absorption of food. The endodermal cells of the midgut break down while secretory cells and their contents are discharged into the lumen and fresh cells are formed. From the anterior end of the midgut arise eight tubular *hepatic caeca.* From the posterior end 70-80 very fine, thread-like yellow *Malpighian tubules* are given out.

3. ***Proctodaeum.*** Its wall is also made up of ectodermal epithelium and lined internally with cuticle. It consists of three parts ilium, colon and rectum. At the junction of mesenteron and ilium are present Malpighian tubules arranged in six groups. The inner surface of rectum is raised into six longitudinal ridges, the *rectal papillae* which help in the absorption of water. The rectum opens out through the anus.

II. **Digestive glands.** Associated with the alimentary canal the digestive glands are salivary glands and hepatic caecae.

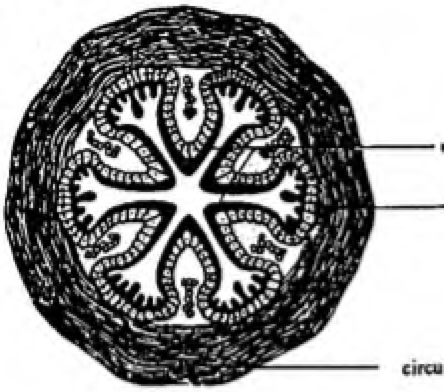


Fig. 49.9 *Periplaneta*. T.S. of gizzard.

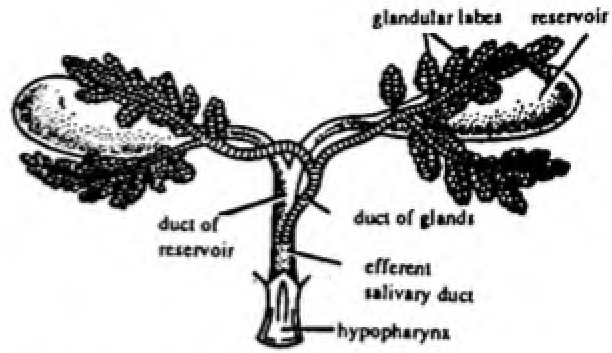


Fig. 49.10 *Periplaneta*. Salivary glands.

1. *Salivary glands*. There are a pair of diffused whitish salivary glands, one on either side of crop in the thorax. Each gland has two branching glandular parts whose ducts form a common glandular duct. Between two branches of each gland lies a thin walled sac-like reservoir. The ducts of both the reservoirs unite to form common reservoir duct which opens into the hypophanynx. The common glandular duct opens into the common reservoir duct.

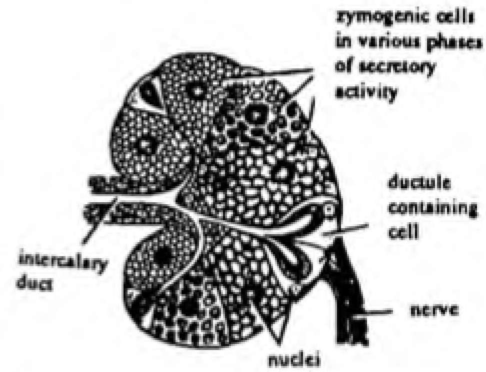


Fig. 49.11 *Periplaneta*. Section of salivary gland.

Each gland consists of several secreting *acini* or *lobules* in grapelike clusters and connected together by fine tubules. Two types of cells are found in acini, *zymogenic cells* and *ductule containing cells*. Both types of cells secrete saliva which contain enzyme zymase and mucoid substance. *Intercalary ducts* from the various acini join each other and are connected to the reservoir where saliva is stored.

2. *Hepatic caecae*. These are 7-8 finger-like, hollow tubes, ending blindly and open into the midgut. They secrete digestive enzymes.

FOOD AND FEEDING

The cockroach is an omnivorous animal and feeds on all sorts of food except metals, bricks, stones etc. The food is located by the sense of small, whose receptors lie on the antennae and palps. The food is caught and masticated with its mandibles and maxillae. The broken food is pushed into the pre-oral cavity with the help of labrum and other mouth parts. During chewing the food is mixed with salvia brought into the preoral cavity by the common salivary duct. *Amylase* of saliva converts starch into sugar. Digestion of food started in pre-oral cavity by saliva coutinues in the crop. Enzymes from midgut also come into the crop through the gizzard for the digestion of some fats and proteins. From the crop the food reaches gizzard where it is ground by the contraction and expension of muscles and the chitinous teeth. The food is than filtered by the bristles. In the mesenteron the food is acted upon by the enzymes secreted by hepatic caecae and the lining of midgut. The secretion contains many enzymes such as *peptase, trypase, invertase* and *lipase*. The digested food is absorbed by the lining of midgut and hepatic caecae.

In the midgut, *peritrophic membrane* is formed round the food for the protection of the lining of it from the abrassion by hard indigestible particles in the food. The membrane is a thin chitinous tube formed of the secretion from the funnel-like extension of the gizzard round the food. It is permeable to both, the enzyme and digested food.

The undigested food reaches the rectum through hindgut. The absorption of water takes place in the rectum and the undigested food is converted into almost solid faeces. The faeces is temporarily stored in the rectum from where it is passed out at interval through the anus.

CIRCULATORY SYSTEM

The circulatory system is poorly developed. It is of *open type* i.e. the blood vessels open into spaces and not into capillaries. Thus the blood comes in direct contact with tissue. There are three main parts in the circulatory system.

1. Haemocoel

2. Heart

3. Blood

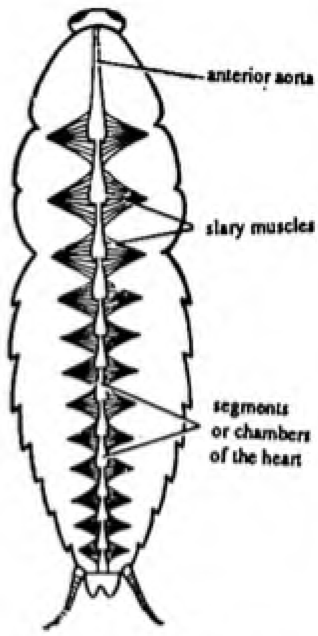


Fig. 49.12 *Periplaneta*. Heart in dorsal view.

1. **Haemocoel.** The haemocoel devoid of true epithelial lining. It is filled with haemolymph. It is partitioned by a dorsal and a ventral diaphragm into three sinuses - (i) the dorsal *pericardial sinus*, containing the *drosal blood vessel* or *heart*, (ii) the middle *preivisceral sinus*, containing the gut, and (iii) the ventral *perineural* or *sternal sinus*, containing the nerve cord. The diaphragms or septa are provided with pores or *fenestrae*. The ventral diaphragm also extends as septa into the legs. In each leg the septum divides its cavity into two sinues, one for the outward and the other for inward flow of blood.

The pericardial septum is slightly budged upwards. There are a series of paired triangular muscles, the *alary muscles* attached to the pericardial septum by their broad bases and to the terga by their pointed ends. There are 12 pairs of alary muscles in *Periplaneta*.

2. **Heart.** The heart is a long, muscular contractile tube extending along the middorsal line just beneath the terga of thorax and abdomen. It is enclosed in the pericardial sinus. It is composed of 13 chambers, each chamber communicating by a valvular opening (*auricular valve*) with the one in front of it. The chambers communicate to the pericardial sinus by paired lateral openings called *incurrent ostia*. Ostia are also valvular allowing the entry of blood from the pericardial sinus into the heart. The heart is closed behind and is continued infront as a short tube, the *aorta* which opens into the haemocoel of the head. It is provided with *aortic valves*.

Nutting (1951) has described that in roach' *Blaberus*, there are 6 paired lateral segmental blood vessels of which 2 thoracic and 4 abdominal pairs. Through these blood vessels the blood leave the heart.

3. **Blood.** The blood or haemolymph is contained in the haemocoel. It is only the extracellular fluid and makes 15-75% volume of the insect.

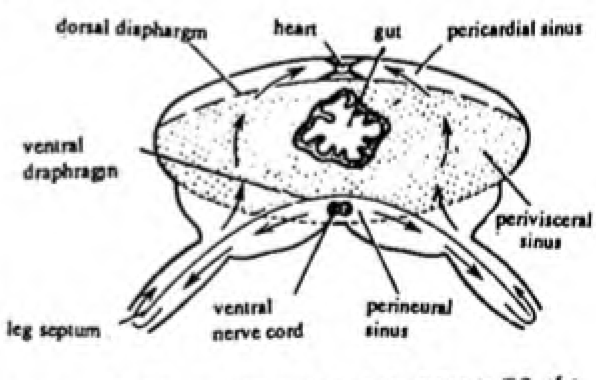


Fig. 49.13 *Periplaneta*. Course of blood circulation in T.S. of a thoracic segment.

It consists of liquid plasma and numerous colourless blood cells or *haemocytes*. There are about seven types of haemocytes (*Wigglesworth*, 1965). The principal function of the haemocytes is *phagocytosis* i.e. the ingestion of small solid particles. Some haemocytes fulfil the function of food storage since they contain inclusion of glycogen and fat. In insect the respiratory pigment is absent in blood and thus plays no role in respiration. Instead it helps in transportation of digested food materials, collects nitrogenous. waste products from the tissues and brings to the extractory organs for their removal, healing of wound transportation of the hormones etc.

Circulation of blood. The heart is the principal pulsatory organ and undergoes rhythmical contractions which are brought about by the muscle fibres of its walls. The rhythum of the heart appears to be purely myogenic (*Miller*, 1974) though it is influenced by nervous system. Contraction of the heart takes the form of a wave of peristalsis which runs forward from the posterior end. The blood is poured into the head sinus through the dorsal aorta. These is an *accessory heart* at the base of each antenna which send haemolymph into the antenna. From the head sinus, the haemolymph flows into the perivisceral and sternal sinuses. Now the alary muscles contract, so that the pericardial septum becomes flat. This increases the capavity of pericardial sinus. The haemohymph, therefore, flows from periviscercal sinus to the pericardial sinus through the perforations of diaphragm. On

relaxation of the alary muscles, the pericardial diaphragm bulges upwards, they press blood which enters the heart through ostia. The rate of heart beat in *Periplaneta* in 49 per minutes.

RESPIRATORY SYSTEM

In the cockroach respiration takes place by means of internal air tubes known as *tracheae.* These ramify through the organ of the body and its appendages, the finest branches being called *trachioles.* The air generally enters the tracheae through *spiracles,* which are lateral in position in the thoracic and abdominal region.

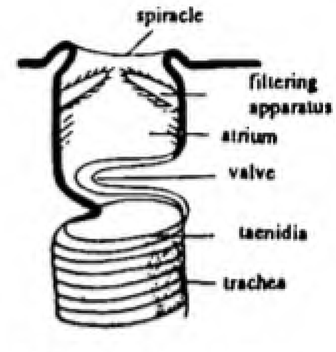


Fig. 49.14 *Periplaneta.* A spiracle with filtering apparatus, valve and atrium.

1. Spiracles. The spiracles are derives from the mouths of the ectodermal invagination which give rise to the *tracheal system.* Ten pairs of piracles are found in *Periplaneta* 2-pairs in thorax and 8 pairs in abdomen. The first pair lodge between prothorax and mesothorax, second pair between mesothorax and metathorax and remaining 8 pairs are present between the sternum and pleuron of first to eighth abdominal segments. Each spiracle is surrounded by an annular sclerite called *peritreme* and leads into a chamber called *atrium* from which the trachea arises. The spiracle is providided with the *closing apparatus.* The apparatus consists of one or more muscles with associated cuticular parts and by closing the spiracular aperture, prevents excessive loss of water vapour. The atrium is a specialised region, lacking taenidia or intima, provided with hairs which prevent the entry of sand particles with air. The first pair of spiracles is the largest and is in the form of oblique slit. The second pair is smaller and simpler than first.

2. Tracheae. The tracheae are elastic, cuticular tubes, which, when filled with air, have a silvery appearance in dissections. The cuticular lining or *intima* is continuous with that of external body surface and secreted by the tracheal matrix cells derived from epidermis. A delicate basement membrane forms the outermost coat of the tracheae. There are 3 pairs of large, parallel, longitudinal *tracheal trunks,* one dorsal, one ventral and one lateral in position. These are connected together by *transverse commissures.*

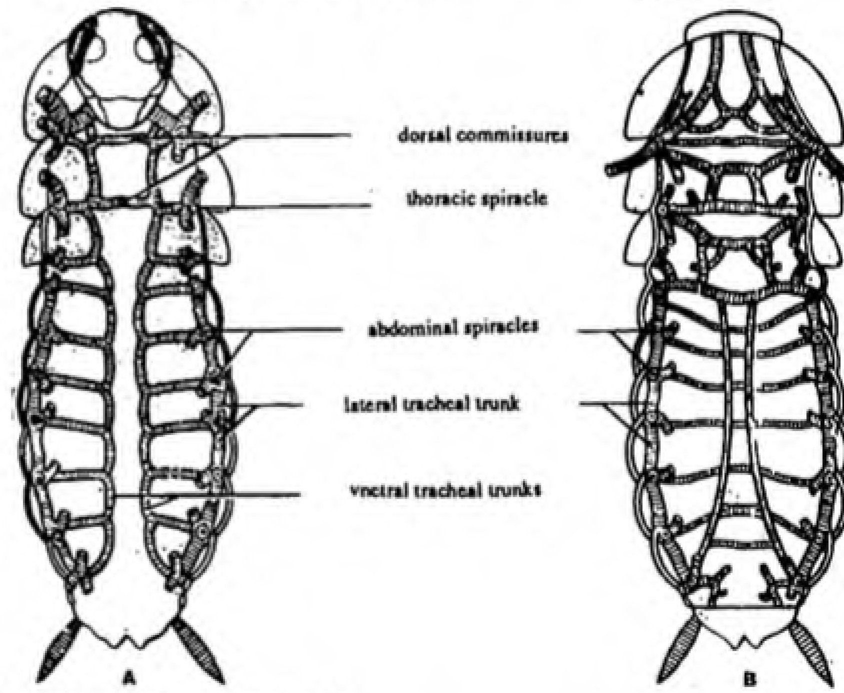


Fig. 49.15 *Periplaneta.* Salivary glands.

The tracheae branch and rebranch to from ultimate finer branches called *tracheoles.* They have a diameter of only one micron. Their cavities are intracellular, i.e., each tracheole is made of a single cell. Their walls are very thin and devoid of intima, instead they are lined by a protein, the *trachein.* They are permedable to water and are usually filled with a fluid in which oxygen dissolves and diffuse to the tissue.

MECHANISM OF RESPIRATION

By the contraction and expension of *tergosternal muscles* the terga and sterna contract and expand as a result of which inspiration and expiration takes place. Expiration is an active process where as inspiration is passive. The first pairs of thoracic and abdominal spiracles, always remain open but the remaining open during inspiration but close during expiration. Air enters the spiracles during inspiration and comes to the tracheae, then it comes to the tracheoles which contain fluid, the oxygen dissolves in these fluid and reaches the cells of the tissues. Opening of the spiracles and subsequent diffusion of air are due to the stimulation

of spiracles by carbon dioxide. In expiration some carbon dioxide may pass out through the spiracles but the major part of it diffuses out through the cuticular covering of the body. Carbon dioxide also dissolves in the plasma and reaches the body surface which is permeable to gases and allows carbon dioxide to pass out.

When the cockroach is running, the oxygen requirement increases and special respiratory movements of the abdomen start. The fluid present in the tracheoles is withdrawn into the body cells and the air rushes forward to take its place, the oxygen reaches itself directly to the cells of the body tissues. It is not supplied through the medium of blood or haemolymph.

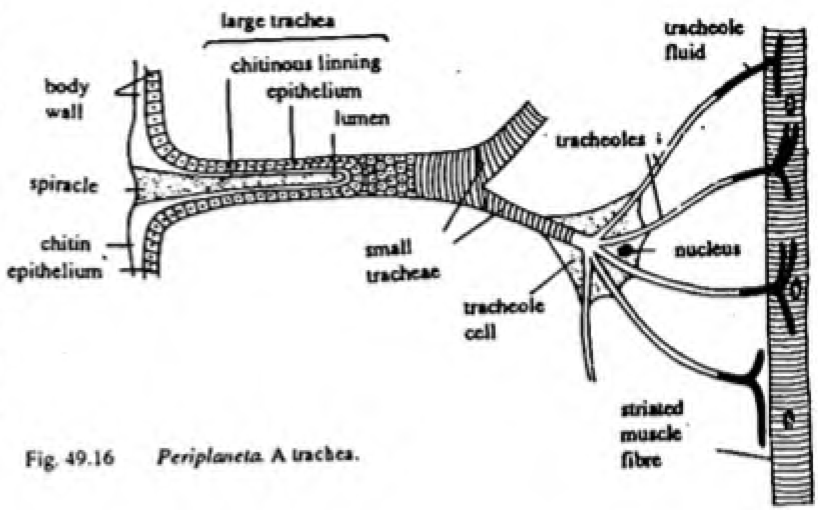


Fig. 49.16 *Periplaneta.* A trachea.

EXCRETORY SYSTEM

The *excretory system* is simple in cockroach. The principal excretory organs are the *Malpighian tubules*, working in conjunctions with the hindgut. Some haemocoelomic structures, such as the *nephrocytes, fat bodies* etc. have also been regarded in the past as excretory organs.

Malpighian tubules. They are long, slender blind tubes lying the haemocoel where they are freely bathed by the haemohymph. They open at their proximal ends into the intestine, near the junction of mesenteron and hind gut. They are regarded as derivatives of ectodermal proctodaeum. The Malpighian tubules are richly supplied with a reticulum of fine tracheae whose larger branches serve to maintain these organs in position. There are between 60 and 150 in number and are arranged in 6-8 bundles. Each tubule is about 16 mm. long and 0.5 mm. in diameter and is lined by glandular epithelium with a characteristic *brush border*. The glandular cells extract the uric acid, water and inorganic salts from the haemolymph and secrete them into the lumen from where they flow into the hind gut to be eleminated with the faeces. The reabsorption of water takes place in the rectum. The Malpighian tubules have been observed to show peristaltic movements that bring more and more haemolymph in their contact.

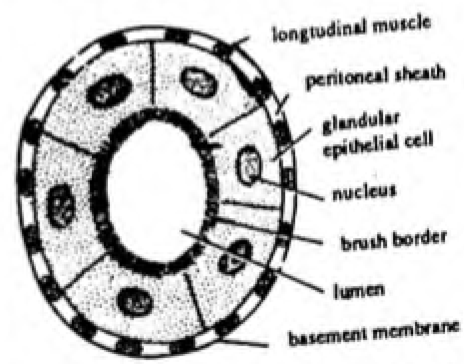


Fig. 49.17 *Periplaneta.* T.S. of Malpighian tubule.

The role of Malpighian tubules in regulating water balance and ionic concentrations presents complex biophysical problems still not fully elucidated.

Fat bodies. The fat-body is composed of irregular masses or lobes of rounded or polyhedral cells. These are usually vacuolated and contain inclusions of various kinds. The fat bodies are derived from mesoderm by differentiation. The nitrogenous waste products (uric acid and urates) are present in the form of excretory granules in specialized *urate cells* of the fat body. Throughout the life these products are deposited in these cells.

Besides urate cells the other types of cells present in the fat body are: (i) *Trophocytes* which store fat, glycogen and proteins as reserve food materials. (ii) *Oenocytes* which are believed to secrete cuticular lipids and it has been suggested that they may be the site of ecdysone production and (iii) *Mycetocytes* which are filled with symboint micro-organisms that help in amino acid synthesis.

Uricose glands. The mushroom glands of male cockroach possesses long, blind tubules at its periphery called *uricose glands*.

These gland store uric acid and discharge it over the spermatophore during copulation.

Cuticle. some excretory substances probably accumulate in cuticle of the body wall shed along it during *ecdysis* or *moulting*.

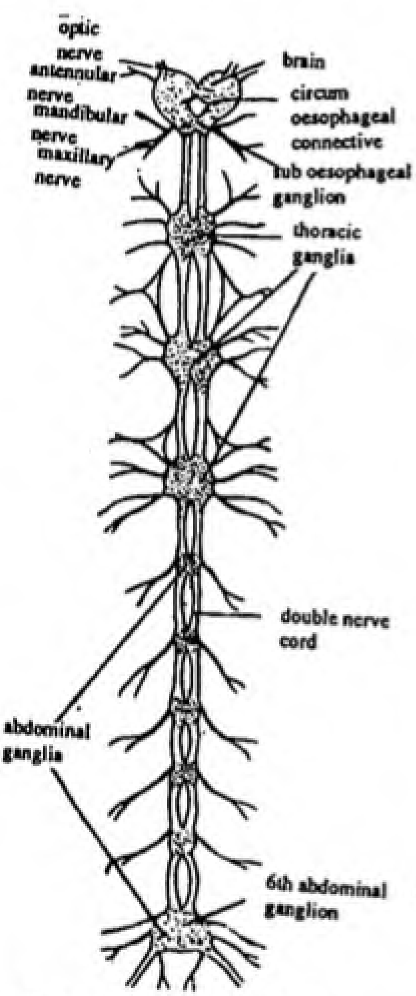


Fig. 49.18 *Periplaneta.* Nervous system.

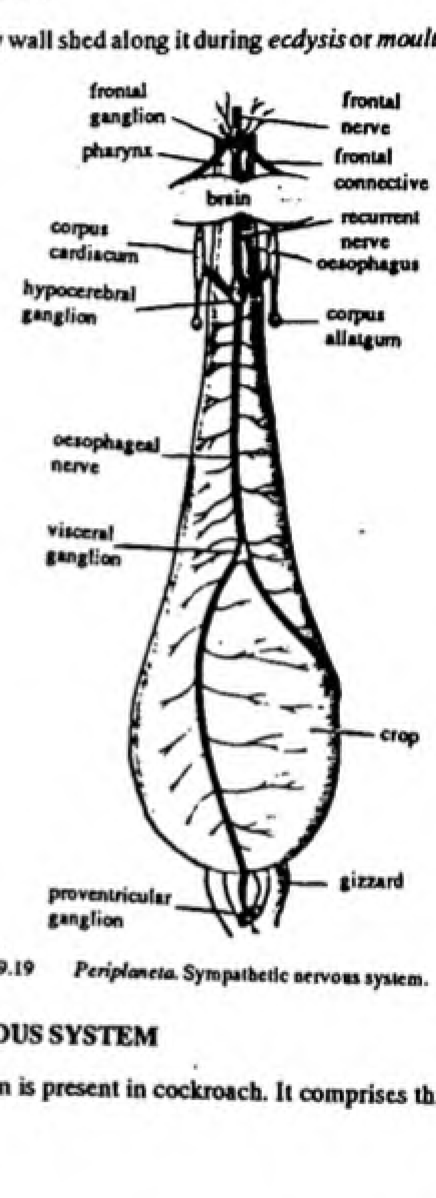


Fig. 49.19 *Periplaneta.* Sympathetic nervous system.

NERVOUS SYSTEM

A well developed nervous system is present in cockroach. It comprises three main parts:

I. Central Nervous System

II. Peripheral Nervous System

III. Autonomic Nervous System

1. Central Nervous System. It comprises *brain* or *cerebral ganglion, suboesophageal ganglion, circumoesophageal connectives* and *nerve cord.*

The *brain* or *supra-oesophageal ganglion* is a large and bilobed mass located in the head above the oesophagus almost between the bases of the antennae. It represents three fused ganglia of the head region. It is divided into three parts - the *protocerebrum, deuterocerebrum* and *tritocerebrum.* The remaining three ganglia of the head fuse to form the *sub-oesophageal ganglion* which lies below the oesophagus, posterior to the brain. The brain and the sub-oesophageal ganglion are connected together, on either side, by a *circum-oesophageal connectives.*

From the sub-oesophageal ganglion, a double *ventral nerve cord* runs posteriorly along the mid-ventral line of the thorax

and abdomen. The nerve cord bears nine ganglia, three in the thorax and six in the abdomen. The last abdominal ganglion is the largest, representing many fused ganglia of the posterior abdominal segments.

II. **Peripheral Nervous System.** From the central nervous system arise nerves which go to different parts and constitute the peripheral nervous system. From the brain three pairs of nerves arise *optic, antennary* and *labrofrontal* nerves and go to the eyes, antennae and labrum respectively. From the sub-oesophageal ganglion also three pairs of nerves arise and go to the mandibles, maxillae, and labium as *mandibular, maxillary* and *labial* nerves. Several pairs of nerves arise from each ganglion of the nerve cord and they innervate the various parts of their segment; but from the last abdominal ganglion five pairs of nerves arise and go to the last five segments of the abdomen, one pair to each segment reproductive organs, copulatory appendages and anal circi.

III. **Autonomic Nervous System.** It comprises a few ganglia and connectives. A *frontal* ganglion is situated on oesphages just in front of the brain. It is connected with the brain by a *frontal connective.* From the frontal ganglion a median *recurrent nerve* passes backwards and bears the occipital ganglion behind the brain. From the occipital ganglion three nerves arise, 2-lateral and one median. The lateral nerves meet the corpora cardiaca. The median nerve runs backwards over the oesophagus and joins the *ingluvial ganglion* which is situated on the crop. From the ingluivial ganglion, a pair of nerves proceed backwards over the alimentary canal.

SENSE ORGANS

Cockroach has a variety of sense organs meant to catch the stimuli of touch, taste, smell, sound and vision. Basically all these organs, except the visual organs, are build on the same pattern and are in the form of minute projections called *sensillae.* The sensillae may be present in enormous numbers and are supplied with a sensory nerve fibre.

A typical sensilla is derived from a hair-like process of the cuticle or seta which is set on a small circular membrane. Below this membrane is a large *sense cell* connected, on one side, with the nerve fibre and on the other with the setal process. Usually two more cells are associated with seta. A large *trichogen cell*, which is responsible for secreting seta and a *tormogen cell* which gives rise to the membrane. The typical sensilla is modified into two types - the *tactile sensillae* in which there is a single sense cell and the *chemical sensillae* in which there is a group of such cells. In the latter, the seta itself is short and permeable to the fluids or vapours. The *acoustic sensillae* are so modified as to be present in groups and associated with certain membranes which vibrate by sound waves.

In *Periplaneta*, tectile sensillae are distributed over the general body surface but specially on antennae, palpi, anal cerci and distal segments of the legs; olfactory sensillae are present on the antennae; gustatory sensillae on the palpi and other mouth parts and the legs; and acoustic sensillae on the base of the abdomen.

Compound eyes. Of all the organs of special sense, the most important is a pair of large, sessile, *compound eyes* in the form of black, kidney-shaped patches on the sides of the head capsule. Each consists of about 2,000 visual elements or units, called *ommatidia*, similar in structure to those already described for the prawn in Chapter 47.

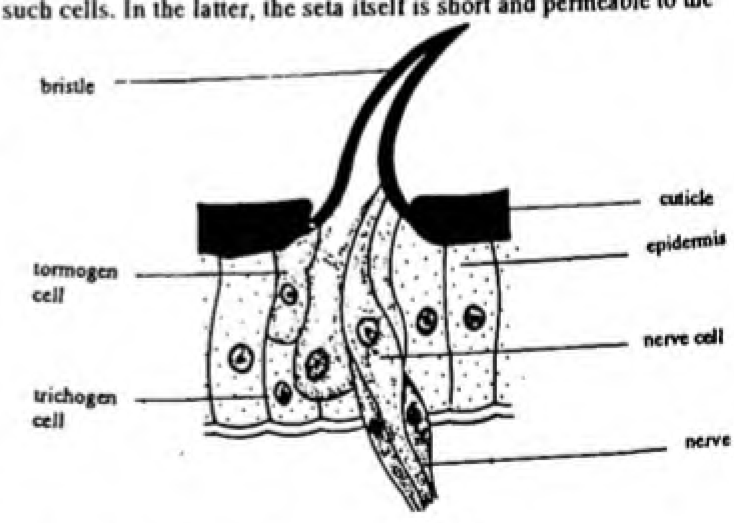


Fig. 49.20 *Periplaneta.* A sensila.

The pigment cells are, however, not retractile in *Periplaneta* so that it can see only by apposition images.

Ocelli. At the base of each antenna there is a fenestra which represents an ocellus or simple eye. Each comprises a single lens and is capable of preceiving only the light and not the image formation.

ENDOCRINE GLANDS

The anterior part of body contains a number of endocrine glands, many of which, from their position in the head are known

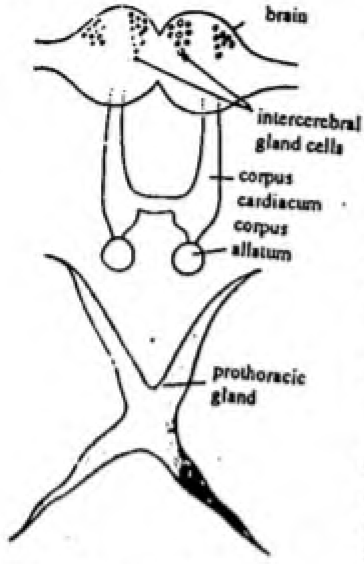


Fig. 49.21 *Periplaneta*. Endocrine glands.

as *retrocerebral glands*.

1. **Neurosecretory cells.** These cells lie in the brain. They are typically arrnaged in clusters in the pars-intercerabralis of the protocerebrum and in a more lateral group on each side. They secrete a hormone known as *brain hormone* which is probably a protein or mixture of proteins with molecular weight 40,000. The hormone activates the prothoracic glands to secrete their hormone.

2. **Corpora cardiaca.** Situated in close association with the aorta behind the brain is a pair of small bodies, the *corpora cardiaca*. Each is connected to the protocerebrum by a pair of nerves and to the hypocerebral ganglion by a single nerve. The hormome of corpora cardica are those produces by its intrinsic cells and by the neurosecretory cells of the brian. The intrinsic cells are known to secrete at least two metabolic hormones, the *hyperglycemic* and *adipokinetic*.

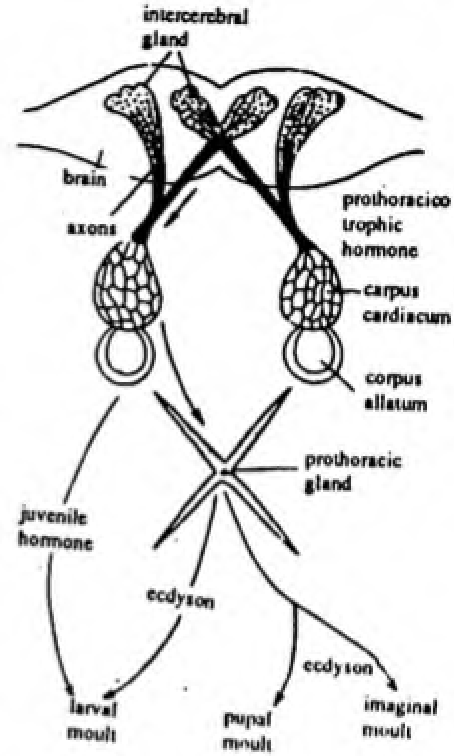


Fig. 49.22 *Periplaneta*. Interaction of harmones.

3. **Corpora allata.** These endocrine glands are situated laterally behind the brain, usually near the corpora cardiaca. They are paired, spherical or oval bodies. The hormone secreted by these glands is known as *juvenile hormone* or *neotenin* whose most important function is to inhibit the realization of imaginal characters during postembryonic development. During last larval or nymphal instar the corpora allata become inactive and the resulting change in hormonal balance leads to metamorphosis. In adults it exerts a gonadotrophic influence in the adult females. There is no gonadotropic effect in males but their secretion may be needed for full development of the accessory reproductive glands and for normal sexual behaviour (*Barth* and *Lester*, 1973).

4. **Prothoracic glands.** These are paired structure, also known as *thoracic glands, pericardial glands, ecdysial glands* or *ventral glands*. They are fairly large and irregular glands situated in prothorax and are well supplied with tracheae and in most cases they are provided with nerves. They secrete a hormone known as *ecdysone* which controls moulting of the mymph. These glands atrophy completely in adult insect.

REPRODUCTIVE SYSTEM

The cockroach is unisexual with a distinct sexual dimorphism.

Male Reproductive Organs. The male reproductive system comprises a pair of testes, vasa deferentia, ejaculatory duct, seminal vesicles, mushromm gland and conglobate gland.

Testes. A pair of testes, lying embedded in the fat body, on either dorso-lateral side of the 4th to 6th abdominal segments. Each testis is a trilobed structure and consists of numerous small whitish *follicles* arranged in longitudinal series. In the adult they become nonfunctional and reduced.

Vasa deferentia. From the hind end of each testis, there starts a fine duct, the vas deferens. The two vasa deferentia run backwards and inwards to open into a wide median duct, the *ejaculatory duct*.

Ejaculatory duct. The ejaculatory duct arise in 7th segment runs backwards and opens out at the male genital aperture.

Mushroom gland. It is present at the junction of vasa deferentia and ejaculatory duct. The mushroom gland or *utricular gland* consists of a number of blind finger - like diverticula opening into the anterior end of the ejaculatory duct. The diverticula are of the three types: (i) long slender tubules known as *utiriculi majores* or *peripheral tubules* arising from the anterior end (ii) short tubules, the *uticuli breviores* making up the major portion of gland and (iii) postero-median short but relatively bulbous tubules known as *seminal vesicles.*

Phallic or conglobate gland. It is a large, white elongated, sac-live structure lies beneath the ejaculatory duct that opens out near the male genital aperture. Its function is unknown.

External genitalia. The genital pouch lies below the 9th and 10th abdominal terga. It contains the dorsal anus and ventral male genital opening. Associated with the latter are the *phallic organs* or *gonopophyses* which help in copulation.

The gonapophyses consist of three irregular chitinous processes, the left, right and ventral *phallomeres.* (i) The right phallomere consists of two horizontal opposing plates, a sickle-shaped hook. (ii) The left phallomere possesses a broad base, from which arise several lobes or arms. A long slender lobe, the *titillator*, with a curved hook, lies on its extreme left. On its right is a short lobe, the *pseudopenis*, with a broad hammer-like head. Inner to it are three short, soft lobes, one of which, called the *aspirate lobe*, bears a curves hook. (iii) The ventral phallomere is a brown broad plate without lobes. It lies close to the gonopore.

The sperms pass into the seminal vesicles and are glued together to form a *spermetophore* from the secretion of seminal vesicles. A spermatophore is pear-shaped body, about 1.33 mm in diameter and its wall composed of three non - cellular coats. The first coat is secreted by the secretion of long tubules of utricular gland and sperms flow into it. The second wall is secreted by the secretion of ejaculatory duct and the third wall is secreted by the secretion of phallic gland.

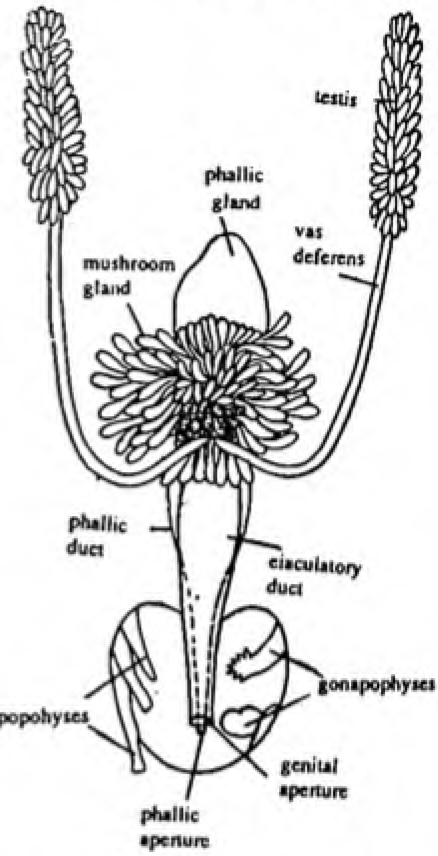


Fig. 49.23 *Periplaneta.* Male reproductive organs.

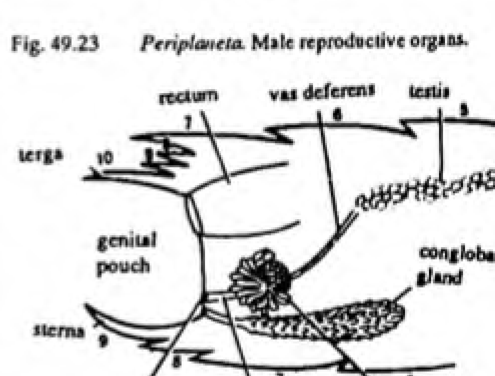


Fig. 49.24 *Periplaneta.* Male reproductive organs in lateral view.

Female Reproductive Organs. The female reproductive organs comprises, ovaries, oviduct, vagina, gynatrium, collaterial glands and spermathecae.

Ovaries. There are a pair of ovaries lying between 2nd to 6th abdominal segments. Each ovary is made up of 8 ovarioles. Which are yellowish in colour. Each ovariole is made up of 5 parts: The anterior most thread-like structure called *terminal susponsary ligament* which is syncytical. It is followed by *germarioum* containing cells at an early stage of egg formation. It is followed by *vitellarium* containing mature ova and gives beaded appearence. It is followed by *egg chamber* which contains only one mature ovum. It is followed by *perdical*

Oviducts. Posteriosly all the eight ovarioles of each ovary join to form a wide oviduct.

Vagina. It is a formed by the union of both the oviducts. The vagina opens into the gynatrium by a slit-like female genital pore situated in the 8th segment.

Spermathecae. There is a pair spermethecae of unequal size, one spermethecae being larger than the other. The two unite to form a short common duct which opens into the genital chamber on a small spermathecal papillae. It is claimed by some

workers that there is a single spermatheca and it has a lateral coiled caecum.

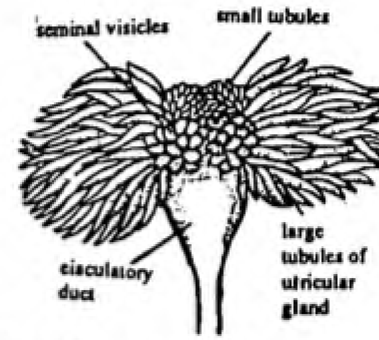


Fig. 49.25 *Periplaneta*. Uricose gland.

Collaterial glands. A pair of highly branched collaterial glands lie behind and above the ovaries. The left gland is more opaque and well developed. The right gland is transparent and less developed. The two open into *gynatrium* or *genital pouch* through their openings. The secretion of these glands provides material for the formation of *ootheca* or egg case round a group of eggs.

External genitalia. The gynatrium or genital pouch is formed by the 7th, 8th and 9th sterna. The sternum of 7th segment is boat-shaped and splits posteriosly into two parts, the *apical lobes* or *gynovalvular plates*. This forms the floor and side walls of the brood pouch. The 8th and 9th sterna form the anterior wall and roof of brood pouch respectively. The pouch is divided into two chambers - a large posterior *oothecal chamber* and an anterior *genital chamber* into which open the vagina, spermatheca and collaterial glands.

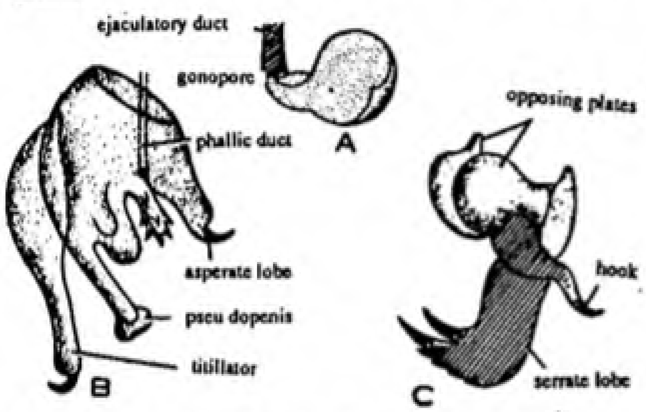


Fig. 49.26 *Periplaneta*. A—Ventral phallomere, B—Left phallomere, C—Right phallomese.

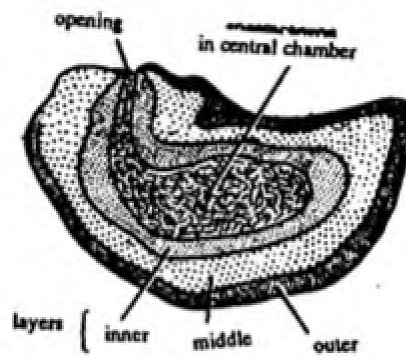


Fig. 49.27 *Periplaneta*. A spermatophare.

The gonopore is surrounded by three pairs of symmetrically arranged, plate-like, chitinous processes, the *gonapophyses*. Of these, one pair arises from the 8th abdominal segment, while the other two pairs belong to the 9th abdominal segment. The gonapophyses serve to hold the ova as they are laid and also aid in the formation of ootheca round them. They, thus, act as *ovipositor*.

Copulation. The breeding season of cockroach is from March to September. Copulation occurs in night. The male and female cockroaches come opposite to each other in such a way that the posterior ends of their abdomen touch each other. The male opens the genital chamber of the female with the help of its titillator and pushes its phallomeres into the genital chamber of the female. At the same time the dorsal phallomere opnes the male genital aperture through which the spermatophore is deposited on the spermathecal papilla. The phallic secretion is now poured over the spermatophore which fixes the spermatophore firmly to the spermathecal papillae and harden to form the third wall of spermatophore. The copulation lasts about an hour and a quarter, after which the two cockroaches separate. The sperms pass from the spermatophore into the spermathecae slowly in the course of the next twenty hours after which the empty spermatophore is discarded.

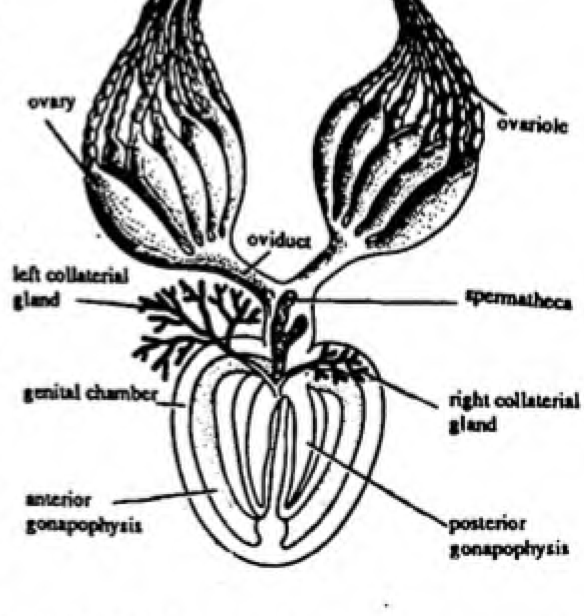


Fig. 49.28 *Periplaneta*. Female reproductive organs.

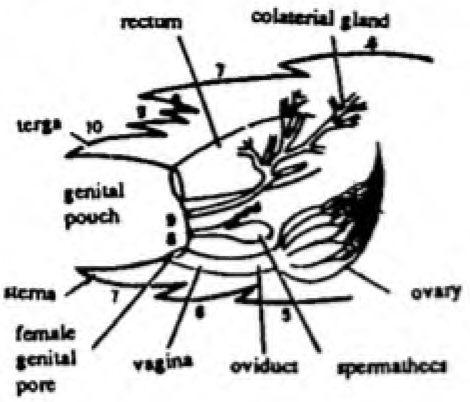


Fig. 49.29 *Periplaneta.* Female reproductive organs in lateral view.

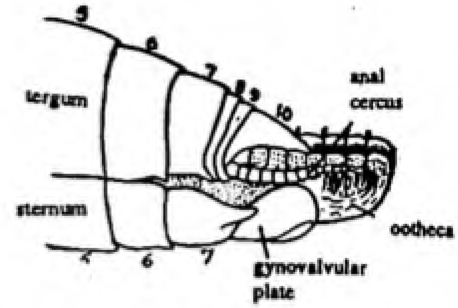


Fig. 49.30 *Periplaneta.* Ootheca protruding from abdomen of female.

Ootheca Formation. The mature eggs are released alternately by each ovary into the common oviduct. They slowly move backward and come into the genital chamber through the female genital pore where they are fertilized. Soon after fertilization, the collaterial glands pour their secretion over the fertilized eggs forming a hard covering over them called ootheca. The ootheca is shaped and moulded by the ovipositor and the wall of oothecal chamber. The ootheca is 12 mm in length. On one side it has a straight crest with a serrated margin. It contains 16 fertilized eggs standing vertically in two rows. The female cockroach moves about with ootheca for several days and then keeps it in a dry, dark and safe place.

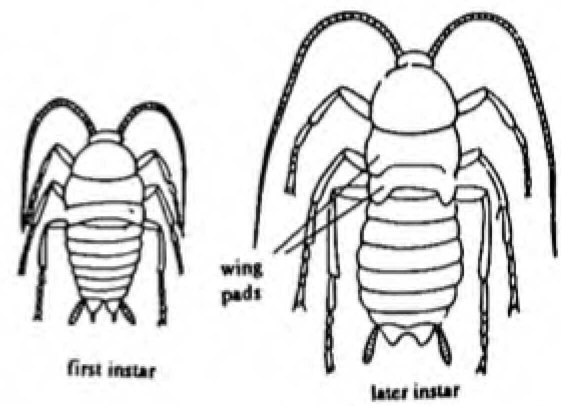


Fig. 49.31 Nymphs of *Periplaneta.* A—First instar, B—Second instar.

Development. The eggs are enclosed in ootheca. Each egg is laterally compressed being concave on one side (future ventral side) and convex on the other. Cleavage is superficial. The nucleus divides and redivided and surrounded by a stellate mass of protoplasm forming the cleavage cells. When cleavage-cells in large number are produced, they migrate to the periphery of the egg forming blastoderm, surrounding the yolk. The egg becomes a blastula, gastrulation takes place shortly after. A differentiation in the gastrula results in an early embryo which separates from the blastoderm by an amniotic cavity. Its three germinal layers gradually from the various organs of nymph.

Hatching. A split of the dorsal keel of the ootheca releases the nymphs. At the time of hatching the cockroaches are white in colour and bear dark eyes, soon the integument becomes dark. The young ones are devoid of wings but in other respect they resemble the adult. These are called *nymphs.* They gradually grow into an adults. During this period the nymphs shed their integument at interval. This process of casting the integument is called *ecdysis* or *moulting.* It is brought about by a hormone secreted by prothoracic gland. The skin cast off by nymph is called *exuviae.* The interval between two moultings is called *stadium.* The form of nymph between two moults is called *instar.* There are about six or seven moults and an equal number of instars in cockroach. The metamorphosis is called paurometabolic development or gradual metamorphosis.

50

MUSCA

The houseflies of the genus *Musca* are very common in human dwellings. They are in plenty during the rainy season, though they appear early in spring and continue till late in winter. In winter most of them die, but many survive in warm places. There are several species of housefly, *Musca domestica* is common in Europe, *M. nebulo* in tropical countries like India, Pakistan, Sri Lanka, Burma etc., *M. vicina* is common in all Oriental countries.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endopterygota
Order	-	Diptera
Genus	-	*Musca*

HABITS AND HABITAT

The houseflies has a world wide distribution. They are abundently around human habitation and filthy and dirty places.

The houseflies are very active and abundant during spring, summer and autumn. They like light, and rest at night on the ceilings, walls and fixtures in the buildings. They become sluggish and decrease in number in November. The survivors pass winter in warm places. The houseflies can comfortably climb a vertical surface and walk upside down on a ceiling with their sticky feet. They are good fliers.

With the help of sponging type of mouthparts they take liquid food. They are unisexual. Their life-cycle show complete metamorphosis.

MOROPHOLOGY

Shape, Size and Colour. It looks somewhat ovoid without wings and nearly triangular with wings at rest. It is about 1.92-2.2 mm in width and 6-7 mm in length. Its dark grey body, with yellowish tinge on the ventral side, has four longitudinal lines on the throax and one black streak on the abdomen.

Division of body. Body is bilateral and is divisible into three regions.

1. Head

2. Thorax

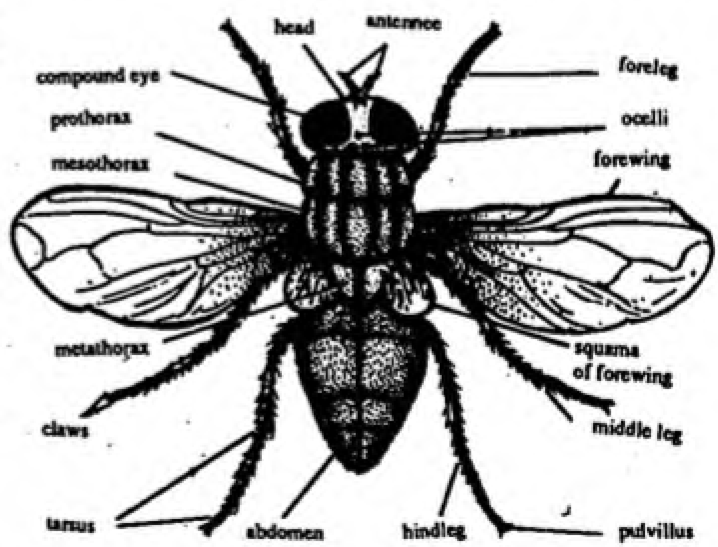


Fig. 50.1 *Musca nebulo*.

3. Abdomen

1. Head. The head is as wide as rest of the body. It is mobile and covered with hair and bristles. It bears following structure:.

(i) *Compound eyes.* The compound eyes are large occupying almost the whole of hemispherical head, thus provides a wide field of vision. Each eye bears 4000 ommatidia.

(ii) *Ocelli.* The ocelli or simple eyes are 3 in number. They lie on the top of the head (vertex) medially between the compound eyes.

(iii) *Antennae.* The antennae are located in a depression in the middle of the front side of the head.

Each antenna is three-jointed; the proximal joint is called *scape*, the middle *pedicel* and the distal *flagellum.* The flagellum is the largest and bears a three-jointed process called *arista.* The two basal segments of the arista are extremely small. The long distal segment bears two series of long hairs or *spinulae.* The antennae serve as sense organs.

(iv) *Mouth parts.* The mouth parts are sponging type adapted to suck a liquid food. It comprises the proboscis which is fleshy and retractile. The proboscis consists of three parts. The basal *rostrum,* middle *haustellum* and the distal *oral disc* or *sucker*. There is a movable joint between, the rostrum and haustellum so that the haustellum can be folded back beneath the rostrum in resting condition. The rostrum bears a pair of dark brown or black, club-shaped *maxillary palps* on its front side. The haustellum has a groove on its front side which contains the *labrum - epipharynx* and the *hypopharynx.* The edges of labrum - epipharynx are rolled to form a tube like *food channel.* The hypopharynx encloses the *salivary duct.* The oral disc comprises oval *oral lobe* or *labella.* The oral lobes are traversed by a network of fine grooves or channels, called *psudotracheae.* All pseudotracheae lead to the centrally located *mouth aperture*, to which the tip of the food channel can be applied so that the liquid food collected by the pseudotracheae can be sucked up by the pumping action of the pharynx. The oral lobes are provided on the undersurface with minute, teeth -like structure for breaking up solid food.

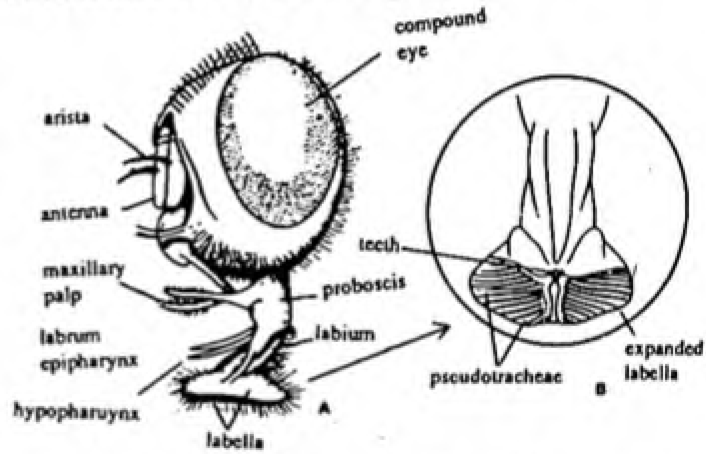


Fig. 50.2 *Musca.* A—Home parts, B—Probascis enlarged.

For feeding, the proboscis is extended and its labella applied to the fluid food. The latter is drawn through the pores of the pseudotracheae into the food channel, whence it is sucked into the alimentary canal by the muscular pharynx.

2. Throax. The thorax comprises indistinct three segments *prothorax, mesthorax* and *metathorax.* It bears three pairs of legs ventrally and two membranous wings dorso-laterally. The wings are present on mesothorax and a pair of knob-like structure called the *halters.* The halters bear sense organs and serve as balancing organs during flight. These also emit buzzing sound during flight.

The *legs* are thickly covered with hairs. Each leg consists of *coxa, trochanter, femur, tibia* and five-jointed *tarsus,* terminating in a pair of curved *claws* with a pair of glandular pads, called *pulvilli* between them. The pulvillus bears a large number of tiny glandular hair which secrete tiny drops of a sticky liquid that sticks the fly to the object upon which it walks or sits. These are called *tenant hair.* Between the pulvilli is a long tapering bristle, the *empodium.*

The thorax has on its sides two pairs of spiracles in both the sexes. The first pair is between the prothorax and mesothorax and the other just below the halteres. They have thickened lips and may be opened or closed to a limited extent by the action of special muscles.

3. Abdomen. There are ten segments in the abdomen, but the first has atrophied and the second is reduced, the third to the sixth are well developed and visible, but segments seven to ten are reduced and lie telescoped inside the anterior segments. In the visible segments the terga are large and extend ventrally. A pair of spiracles are present in the ventral edges of the terga on

segments two to six. In the female the hidden segments seven to ten form a tubular ovipositor which protrudes and can be seen when the fly is depositing eggs.

BODY CAVITY

The body cavity is greatly reduced by air-sacs, thoracic muscles and fat bodies. It is represented by narrow spaces, the *sinuses*, among the viscera. It is not lines by epithelium and contains blood. It is, therefore, called the haemocoel. It is incompletely divided by a horizontal partition, the *pericardium*, into two compartments; the small dorsal sinus that surrounds the heart, and the large ventral sinus that contains the remaining viscera. The two communicate through a passage bounded by pericardial cells.

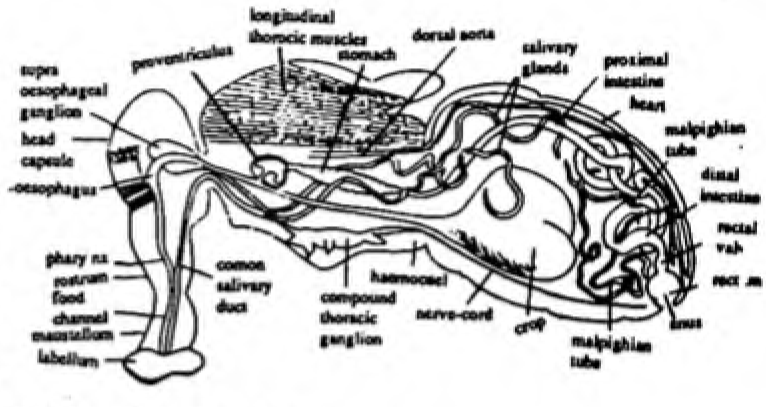


Fig. 50.3 *Musca.* General anetomy.

DIGESTIVE SYSTEM

The digestive system comprises the alimentary canal and digestive glands.

I. **Alimentary Canal.** The alimentary canal is complete and comprising three regions: foregut, midgut and hindgut. The foregut and hindgut are ectodermal in origin and internally lined with cuticle.

(i) *Foregut.* It includes:

Mouth. It is situated in the middle of oral lobes, leads by way of a grooved channel into a pharyngeal bulb.

Pharynx. It is a tubular organ provided with muscles for sucking food. Just within the head capsule, it marges oesophagus.

Oesophagus. It is also a tubular structure passing through the cerebral ganglia. After entering into thorax the oesophagus leads into the *gizzard* or *proventriculus.* Before opening into gizzard, the oesophagus gives off a straight, slender duct which extends the length of thorax into the abdomen, where it expands into a large bilobed muscular *crop.*

Proventriculus. It is a small, circular chitinized sac lying in the prothorax, receiving oesophgus on its ventral side.

(ii) *Midgut.* It includes *ventriculus* and *praximal intestine.*

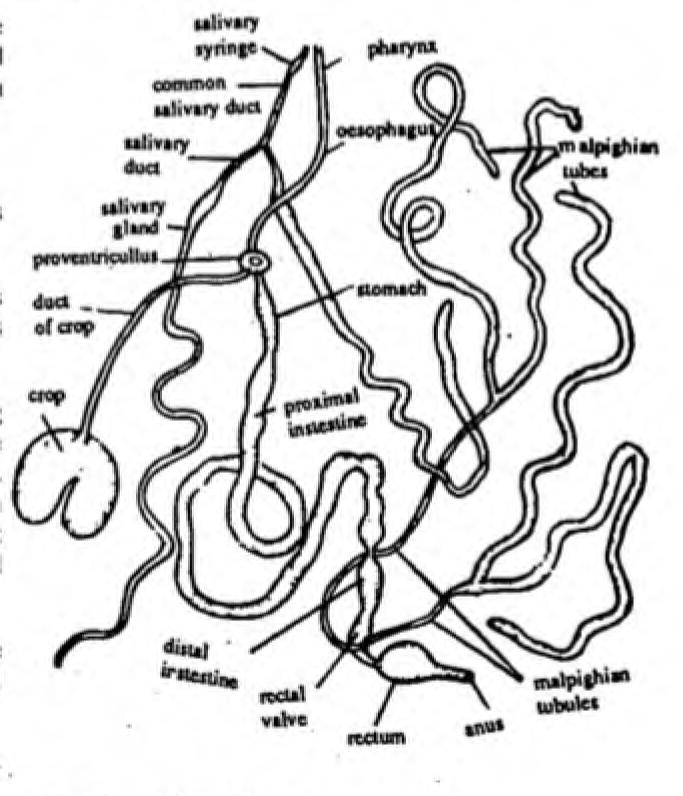


Fig. 50.4 *Musca.* Alimentary canal.

Ventriculus or *chyli stomach.* The proventriculus opens into the ventriculus. It is a straight, spindle-like sac, lines with columanr epithelium. The epithelium is folded to form a large number of *sacculi.* The ventriculus is followed by a long, coiled tube known as proximal intestine.

(iii) ***Hind gut***. It comprises a *distal intestine* and *rectum*. The *distal intestine* is similar as proximal intestine but it is much shorter. It bears a rectal valve. The *rectum* is a dilated sac. It has tuberclated cuticle in anterior part, 4 rectal glands in middle part and thick muscular wall in terminal part. It opens out through the anus.

II. Digestive glands. There are a pair of *salivary glands*. These are wavy tube of uniform diameter. These are lined with cuboidal epithelium. Each gland gives off a *salivary duct* anteriorly. The two ducts unite to form a *common salivary duct*. The duct passes beneath the oesophagus. In the rostrum the common salivary duct is expanded to form the *salivary syringe* that pumps saliva onward to the hypopharynx.

FEEDING AND DIGESTION

During feeding the proboscis is extended and the two expanded oral lobes of the labella are placed on the exposed liquid food. If the food material is solid the fly first pours a little saliva or regurgitated droplets of liquid from its crop to liquefy it and then sucks the liquid. The liquid food fills the tubular pseudotracheae by capillary action. The pseudotracheae then converge into mouth, whence the food rises up the food channel due to the suction force set up in the muscular pharynx. The alimentary canal is long and coiled with the pharynx, oesophagus, crop-gizzard, stomach or midgut and rectum. The two small salivary glands pour saliva on food to hydrolyse starch. Digestion and absorption mainly take place in the mid-gut.

RESPIRATORY SYSTEM

The respiratory system is highly developed. It consists of three components: the *spiracles, air-sacs and tracheae.*

Spiracles. There are 7 pairs of spiracles in a female and 9 pairs in the male. Of which first two pairs are thoracic and rest are abdominal. Each spiracle leads into a shallow *vestibule* which is partly separated by a valve-like mechanism from the *atrium* inside.

Tracheae. In the abdomen, the atria lead into the tracheae where as in the thorax the atria open into large thin walled *air sacs* from which small tracheae extends to muscles and other tissues. The thoracic air sacs send a number of *cephalic air sacs* in the head and a pair of very large *abdominal air sacs* in the abdomen. The cephalic and few thoracic air sacs remain expanded where as the others are collapsable. These are the reservoirs of air. The tracheae branch and rebranch to form the fine tubules, the *trachioles.*

The trachioles participate in the exchange of gases.

CIRCULATORY SYSTEM

The circulatory system of housefly is very simple and open type as found in other insects. There is a muscular tube or *heart* lying in a cavity i.e. the *pericardial sinus* along the mid-dorsal line. It extends the length of the abdomen and is divided into 4 chambers. Each chamber having a pair of opening through which the blood is sucked form the pericardial sinus. The anterior end is continued into a slender *dorsal aorta* or *anterior aorta*. The heart is supported by *alary muscles*. Besides heart there are 4 accessory pulsating organs called *auxillary hearts* at the base of each wings and a few in the thorax which assist in circulation of blood.

The dorsal aorta continue along the stomach and appears to terminate in a mass of cells behind the proventriculus. It pours the blood into the anterior part of haemocoel. The haemocoel is incompletely divided into a large *ventral sinus* and a small *dorsal sinus* or *pericardial sinus*, by a horizontal partition, the *pericardium*.

The blood is colourless and is called the haemolymph. It contains a fluid plasma and numerous blood corpuscles, the *haemocytes*. It does not contain any respiratory pigment. It helps in physiological exchange of materials.

EXCRETORY SYSTEM

In housefly the excretory system consists of one pair of yellowish-green tube-like structures known as *Malpighian tubules*. These are present at the junction of mid-gut and hind-gut. Each tubule is divided into two branches. The branches are very long, highly convoluted and cannot be separated from the fat-bodies.

NERVOUS SYSTEM

In housefly the *supraoesophegeal ganglion, sub-oesophageal ganglion* and *circumoesophageal connectives* are fused to form a common mass which is perforated by an aperture for the passage of oesophagus. The ventral nerve cord bears a *compound thoracic ganglion* which is formed by the fusion three thoracic ganglia.

From brain a median *ocellar nerve* is originated and is supplied to ocellus. A pair of *antennary*, paired *pharyngeal nerves*, paired *labial nerves* innervate their respective organs. Paired *cervical nerves* arise from the nerve cord before joining to the compound thoracic ganglion. It supplies to the muscles of neck. From compound thoracic gaglion a pair of each *prothoracic, mesothroacic* and *metathoracic dorsal nerve* arise which innervate the thoracic muscles. A pair of each of *accessory mesothoracic* and *metathoracic dorsal nerves* arise from the thoracic ganglion and suppliment the corresponding dorsal nerves in supply. To the legs, a pair of each *prothoracic, mesothoracic* and *metathoracic crural* nerves are supplied. Two pairs of *abdominal nerves* are given by the dorsal nerve cord behind thoracic ganglion in the region of thorax. In the abdomen a series of *abdominal nerves* are given alternately on right and left to supply abdomen. The dorsal nerve cord ends in the genital organs.

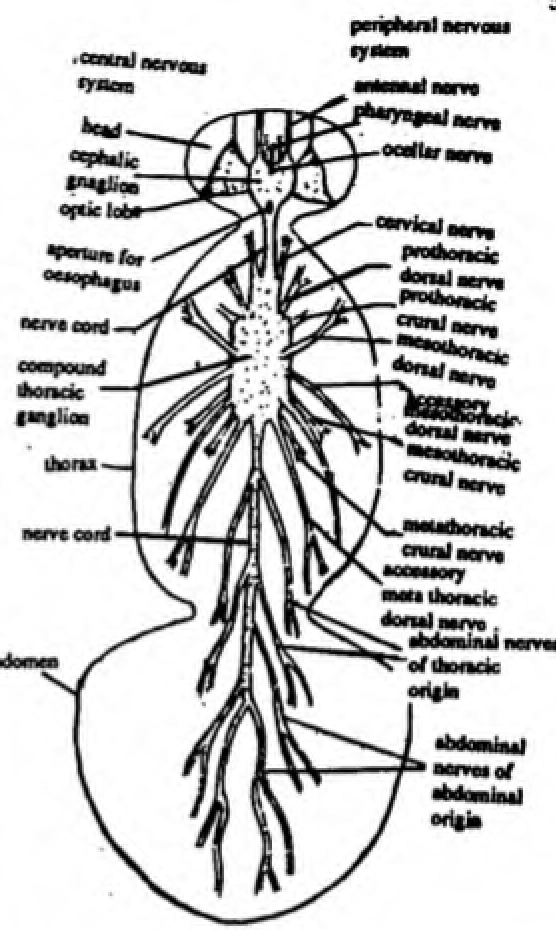


Fig. 50.5 *Musca*. Nervous system.

REPRODUCTIVE SYSTEM

The sexes are separate and are slightly different in size, the female being slightly larger than the male.

I. Male Reproductive Organs. The male reproductive organs consist of a pair of testes, vasa deferentia, ejaculatory sac, ejacultory duct and penis.

(a) *Testes*. A pair of brownish, somewhat pear shaped or pyriform testes are present in 5th abdominal segment.

(b) *Vasa deferentia*. From each testis a duct arises known as vas deferens and extends forward. The two vasa deferentia unit to form a median tube, the ejaculatory duct.

(c) *Ejaculatory duct*. It is a much coiled structure, anteriorly it is wider. It enlarges posteriorly to form ejaculatory sac.

(d) *Ejaculatory sac*. It is a muscular sac like structure supported by ejaculatory sclerites. It helps in ejaculation of seman.

(e) *Penis* or *Aedagus*. The sclerites of 6-10 abdominal segments are modified into the external genitalia. There is a complicated penis. It is made up of a hollow *theca* followed by a delicate, hyaline *glans* bearing a male genital pore.

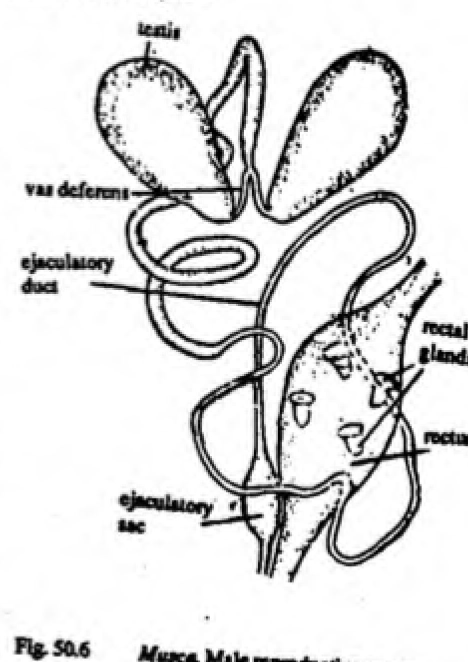


Fig. 50.6 *Musca*. Male reproductive organs.

II. Female Reproductive Organs. It consists of a pair of ovaries, oviduct, spermathecae and accessory glands.

(a) *Ovaries*. These are a pair of whitish, disc-like structures occupy major portion of the abdomen. Each ovary is made up of *ovarioles* and their

number is 70 per ovary. Each ovariole consists of ova in various stage of development.

(b) *Oviducts.* All the ovarioles of each ovary lead into a very short, thin walled tube, the *oviduct.* The two oviducts units to form a curved *common ovdiuct.* It dilates to form *sacculus* which is followed by a still larger *vagina.* The vagina opens out through female genital pore present in the 9th abodominal segment.

(c) *Spermathecae.* These are three (one right and two left) long tubular structures which open into the genital tract at the junction of sacculus and vagina.

(d) *Accessory glands.* A pair of long, tubular glands lying near spermathecae. They secrete a sticky fluid that cover the eggs to adhere them together and to the substratum.

(e) *Copulatory Vesicles.* These are a pair of sac-like structure.

(f) *Ovipositor.* It consist of the abdominal segments 6-9 with long intersegmental membrane between. It normally remains with drawn into the 5th segment.

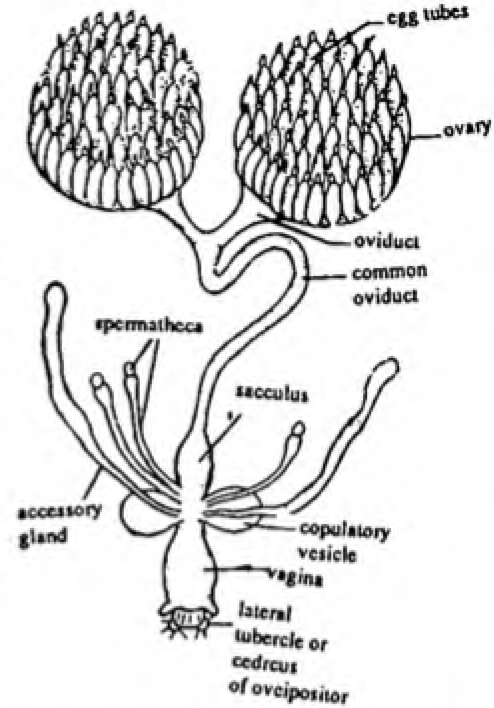


Fig. 50.7 *Musca.* Female reproductive organs.

COPULATION

The flies breed from June to October when they become very active. The greatest breeding activity occurs in the warmest months of August and September. The pairing of the male and female takes place on the ground when at rest, and lasts for a few minutes. The male alights on the back of the female. The female inserts its ovipositor into the genital atrium of the male to receive the spermatozoa. The eggs are laid 6-8 days after copulation.

Oviposition. The rate at which the houseflies breed is amazing. A single fly lays 100-150 eggs. While each fly is able to laye such 5 or 6 deposits in one season. The female extends her ovipositor into the manure dung, decomosing fruits, vegetables etc. Whatever substance it selects and lays eggs.

METAMORPHOSIS

It is complete shows four stages of development as follows:

Eggs. The eggs are small, nearly white and elongate with one end slightly broader than the other. Each egg is about 1 mm. in length and bears two dorsal, rib-like, curved and longitudinal thickenings.

In warm weather the egg takes 8 - 24 hours to hatch.

Larva. The larva, specially called the *maggot,* emerges from a slit along one side of the egg, while growing up the larva cast off its skin twice, thus dividing the larval period into three *instars* (i) from hatching to the first moult that takes 20-30 hours (ii) between the first and second moult taking 24 hours (iii) from second mould till pupation taking about 3 days. The time between two moults is called *stadium.* The larva is a soft, legless, worm-like creature. It is conical is shape, being narrow in front and broad behind. The newly hatched maggot is 2 mm. long. Its body consists of 12 segments and an indisinct head. The head can be withdrawn under the first segment or pseudocephalon. It bears a pair of *oral lobe* bearing minute papillae-like *antennae*, a pair of *maxillae* with photo-receptive

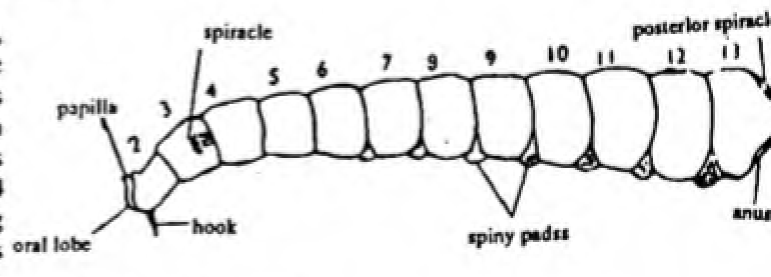


Fig. 50.8 *Musca.* Larva.

papillae, a pair of hook-like *mandibles* and a small *labium*. It is *metapneustic* having only one pair of D-shaped posterior abodominal spiracles with two slit-like apertures in each. The anus is located ventrally on the last segment.

On the anterior border of each of the 6th-12th trunk segments, there is a semilunar pad beset with minute, stuff spines. These *spiniferous pads* are locomotory organs and help the larva in moving backwards and forwards. The body of the larva is covered externally by cuticle.

After first moult a second instar is formed. It is larger than first instar. Besides the posterior pair of spiracles which becomes larger, the 2nd instar acquire an anterior pair of spiracles also. Thus the larva is *amphipneustic*. After second moult, third instar is formed. The third instar is a full grown larva measuring 12 mm in length. The third instar grows in size and ready to pupate within 3 days.

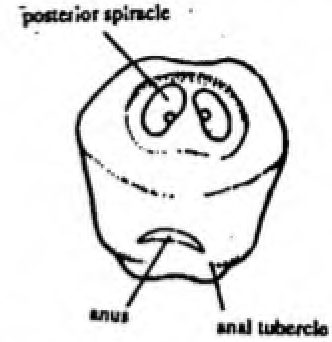


Fig. 50.9 *Musca*. Larval posterior end showing spiracle.

Pupa. When fully matured the larva usually crawls away from its original moist place and travels to some dry and sheltered cervice. Here it rests for sometimes. The emergence of pupa is proceeded by a general contraction of body. Some of the anterior segments are even withdrawn within the body. Thus the larva changes into a pupa without moulting, the last larval skin hardens to form an outer covering of *puparium* which encloses the pupa. Such a pupa is called *coarctate*. It has no chitinous covering of its own but only a soft pupal skin, the outer puparium has been formed by the last larval skin. The puparium is barrel-shaped and it becomes dark brown, externally it is segmented and shows traces of larval spiracles and spiny pads which become non-functional. The pupa takes in air by means of a pair of spine-like *pupal spiracles* projecting between the fifth and sixth segments of the puparium. The pupa is absolutely immobile, and the pupal stage last from 4 to 5 days. During this time internal changes take place, the larval organs are broken down or *histolysis* occurs. The *imaginal buds* of the larva begin to form the organs of the adult, the *histogenesis* occurs in the pupa. Imaginal buds are dormant cells, they are stimulated by a hormore of prothoracic endocrine glands which become active only during metamorphosis and make the imaginal buds grow. By these proces the adult fly or *imago* is formed in the pupa.

When the fly is ready inside the puparium it has a sac like structure on the front of the head known as *ptilinum*. This process aid in the emergence of imago from puparium. After emergence, the ptilinum is withdrawn in the head. Its position is externally indicated by a crescentric slit called *lunule* situated above the base of antennae in the form of 'U'.

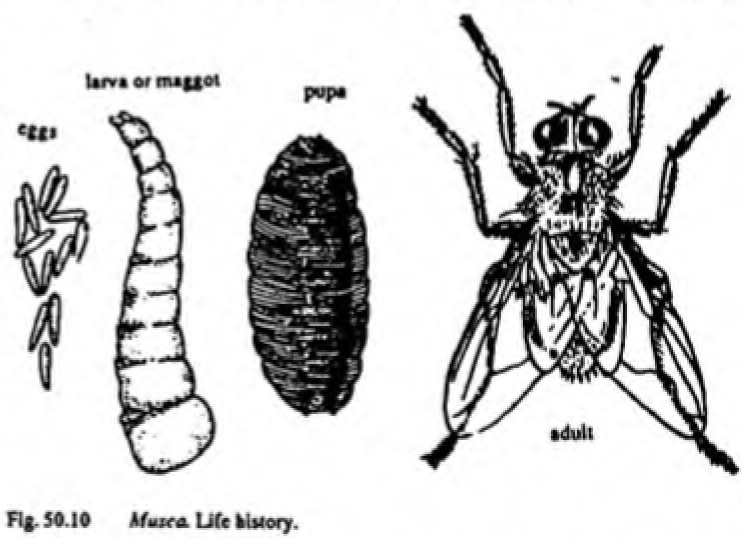


Fig. 50.10 *Musca*. Life history.

Imago. It is somewhat smaller than the adult. The wings are less developed and the colour is light. In the contact of air the wings become hard and somewhat large. The body increase in size and within one or two weeks it becomes adult fly and ready for egg laying.

ECONOMIC IMPORTANCE

The housefly is a very harmful insect besides causing a lot of annoyance, it carries microganisms of several human diseases as it feeds on all eatables as well as manure, faecal matters and decomposing matters. A single fly carries about 33 million germs in its intestine and more that 100 million germs on its legs etc.

1. Dissemination of germs. It spreads various diseases by carrying them on the hairy surface of its body, legs etc. The germs are carried in droppings, vomit spots or via saliva. The diseases are tuberculosis, diarrhoea, typhoid, chlorea, leprosy, plague, anthrax, dysentery, ganorrhoea etc.

Larvae of housefly ingest eggs of a nematode, *Habronema*, and the infection is passed through pupae to adults which transmit it to the horses and to the eyes of children causing conjunctivitis.

Sometimes the eggs are laid on open wounds, where they hatch out as larvae when infected fruits or vegetables are taken, larvae hatch out in the gut, perforate the mucous lining and may cause haemorrhage. This attack by larvae on human is called *myiasis*.

2. Contamination of food. The housefly contaminates our food material by transmitting the infective stages of *Taenia*, *Ascaris* etc.

CONTROL OF HOUSE FLIES

The houseflies are the dangerous enemies of human beings. Therefore, it is very essential that the growth and increase of houseflies and the infection by them must be stopped. It can be done in the following ways:

1. **Preventing their breeding.** Elemination of the breeding media is the first and most important step in fly control. This can be done by:-
   - (a) *Physical method.* All the filth, where eggs can be laid, should be kept covered and periodically removed every week. Open toilets should discouraged.
   - (b) *Chemical method.* The manure or rubbish if accumulated for a longer time, it should be treated chemically with lime, copper-sulphate, crude oil etc. to prevent the breeding of flies.
2. **Destruction of adult flies**
   - (a) *Mechanical methods.* Flies can be collected by baits and then killed. Fly papers, and fly-swatters can also be used.
   - (b) *Chemical methods.* Spraying of houses, barns etc. with DDT, benzene hexachloride etc. is useful. A few drops of 3% formaldehyde solution in a plate of milk attract and kills flies. Repellants like creozote oil and borax, keeps the flies away. A mixture of coal-tar and carbon disulphide can be applied to the wounds of animals. Fumigation by neem leaves is also useful.
   - (3) *Protection from infection by flies.* All types of filth should be kept away or duly covered. The houses must be properly screened and food, fruits and vegetables must not be exposed in houses or markets.

51

MOSQUITOES

Everyone is familiar with mosquitoes. These are common in tropics and found in marshes and damp places. They are a nuisence in places where they occur in large number because of their biting habits. There are 29 gnera and 2000 species of mosquitoes in world. The important genera, as for as human health is concerned, are *Culex*, *Aedes*, and *Anopheles*.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endopterygota
Order	-	Diptera

HABITS AND HABITAT

Mosquitoes are found in damp and marshy places. They are abundant in tropics and sub-tropics. They are active in summer. Mosquitoes are nocturnal, as they come out in night for feeding. During day time they hide in hollows of trees, bushes, dark places of buildings etc. The female feed on the blood of man and other large animals where as male sucks the juices of flowers and fruits. They are oviparous and lay eggs in water. Most of the mosquitos die in winter and extreme hot months of May and June. Some survive hiding in protected places. The mosquitoes can fly for 2-3 hours continuously and cover 20-30 km.

MORPHOLOGY

Shape, Size and Colouration. The mosquito has a slender, delicate and long legged body. It measures 3-4 mm in length. The body colour is greyish black and the wings of *Anopheles* carry dark spots, *Aedes* has no spots on wings but the body has a black and white stripes.

Division of body. Like other insects, the body is divisible into three parts.

1. Head
2. Thorax
3. Abdomen.

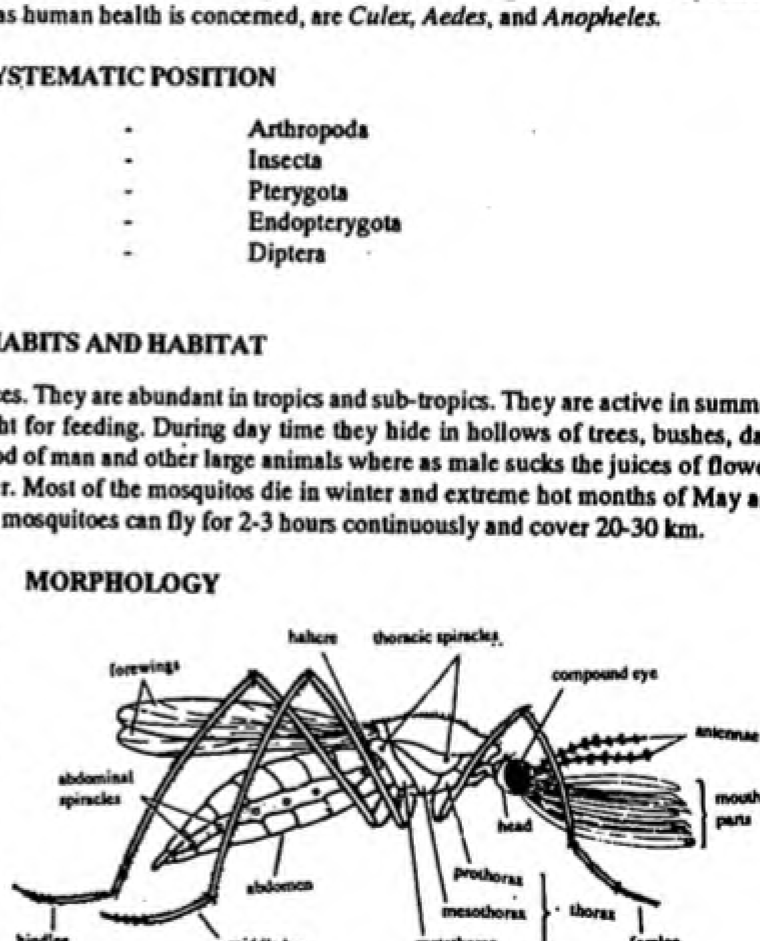


Fig. 51.1 *Culex*. Female

1. Head. The head is globular and highly mobile on a slender neck. It bears a pair of compound eyes, antennae and mouth parts. (i) *The compound eyes* are large and kidney shaped. They occupy a considerable part of the head. The ocelli are absent. The top of the head has an epicranium below which is clypeus. (ii) *The antennae* are filiform, each with 15 joints. The basal segment is the scape which is concealed by a very large globular second segment, the pedicel containing a *Johnson's organ* which is auditory in function, the other 13 joints form a *flagellum* having many bristles lying in rings. The bristles are longer and

much more numerous on the antennae of males giving them a bushy appearance. The antennae of female are with only a few, short bristles. (iii) *Mouthparts.* The mouth parts are of *piercing* and *sucking type*, contained in a proboscis. These are:

(a) A pair of mandibles

(b) A pair of maxillae

(c) Labium

(d) Labrum and epiparynx

(e) Hypopharynx

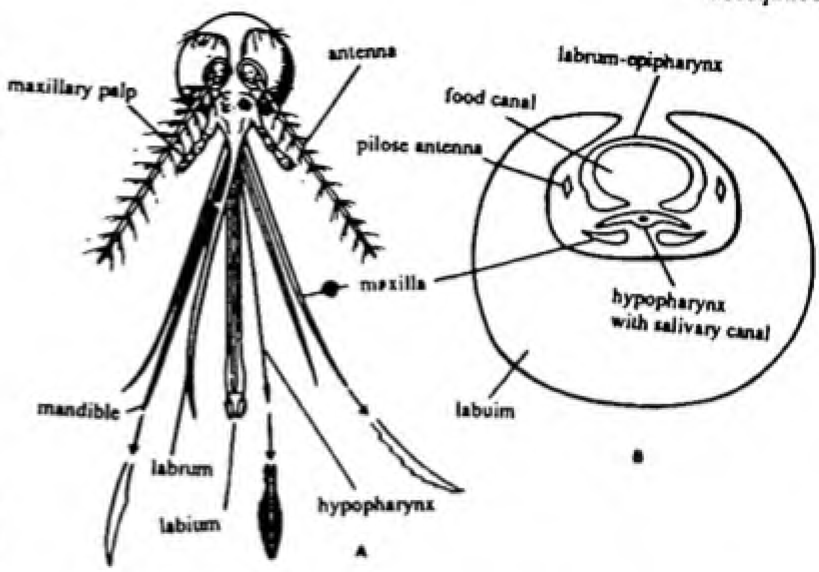


Fig. 51.2 Mouth parts of *Mosquito.* A—Frontal view, B—T.S. of same.

(a) *Mandibles.* The paired mandibles are long, thin and needle-like styles with fine blade-like distal edges. These act as piercing organs and puncture the host skin. The mandibles are, therefore, found only in females and are absent in males.

(b) *Maxillae.* These are also elongated needles very much like the mandible but ending into saw-like blades. These bear a pair of 5 segmented maxillary palps.

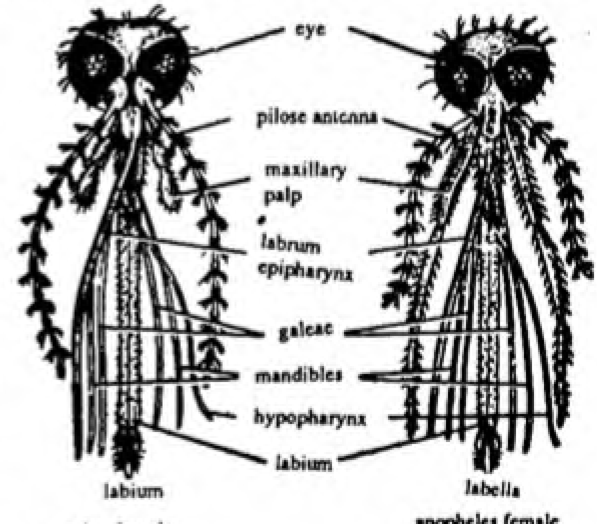


Fig. 51.3 Head and mouth parts of female *Culex* and *Anopheles*.

(c) *Labium.* This is formed by the fusion of 2nd pair of maxillae and is in the form of a median ventral, elongated and flesby *proboscis sheath.* It is like an open gutter of half tube with a groove on its dorsal surface. The tube lodges the mouth-parts and is roofed over by labrum and epipharynx. The free distal end of the proboscis ends in a pair of white pointed lobes known as *labellae.* The labellae are tactile organs clothed with numerous sensory hair.

(d) *Labrum and epipharynx.* The labrum ahd epipharynx are fused together forming a stiff structure with pointed tip. It lies dorsally above the groove of labium and roofing it. It bears ventrally a groove. The groove and hypopharynx forms a food channel.

(e) *Hypopharynx.* It is a long, pointed and flatenned plate like double sword structure. A salivary duct opens at its tip.

2. *Thorax.* The thorax is as usual made up of three segments. The prothorax and metathorax are small whereas the mesothorax is very large and its tergum consists of three sclerites: *scutum, scutellum* and *post-scutellum.* Each segment bears a pair of legs. The legs are long, slender and delicate. They have short coxae, long tarsi and simple cl:.ws.

One pair of wings are present on dorsolaterasl sides of mesothorax. These are membranous. The metathorax bears a pair of *halters* or *balancers.* These represent rudimentary hind-wings, useless for flight and probably sensory in function. These are supposed to produce characteristic sound.

3. *Abdomen.* The abdomen is slender and made up of 10 segments, the first one is fused with metathorax so 9 segments are visible. In male last 3 segments are modified by genitalia. It bears an *anus* on the 8th segment and a *genital pore* on the 9th segment.

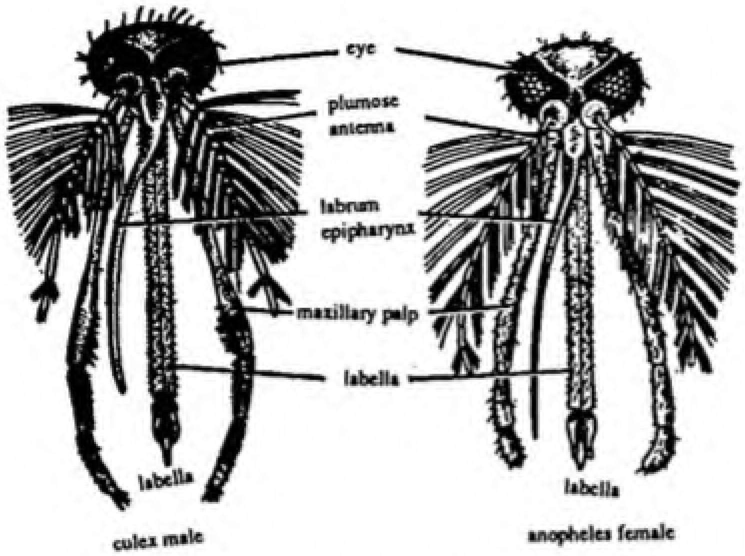


Fig. 51.4 Head and mouth parts of male *Culex* and *Female*.

LIFE HISTORY

The life history in mosquitoes coprises four stages:

1. Egg

2. Larva

3. Pupa

4. Adult

The female always takes a blood meal before egg-laying to have extra nourishment essential for this purpose.

1. Eggs. After mating the female lays eggs on still water, the eggs may be laid on ponds, or pools, or rain-filled containers. The eggs are cigar-shaped, tapering at one end. The eggs laid at night and one *Culex* female may lay 300 eggs. The eggs are laid by side standing erect, and glued together by the legs to form bost-shaped rafts which float on water. Female *Anopheles* lays 40-100 eggs at one time. They float singly do not form a raft. The eggs are pointed at both the ends and have a pair of lateral *air floats*. In *Culex* the eggs have no air float. The egg in the raft are vertical and, their heavier ends downwards. In *Aedes* the eggs are laid singly in moist soil. They hatch when flooded. In *Culex* the eggs lasts 2-3 days where as in *Anopheles* the eggs lasts for 24-48 hours.

2. Larva. In *Culex* the larva hatches out from the egg within 2-3 days. The larva is small, transparent and wriggling creature. The body is distinct into three regions, the head, thorax and abdomen. The *head* is large and rounded structure bearing a pair of compound eyes, a pair of simple eyes or ocelli and complicated mouth parts.

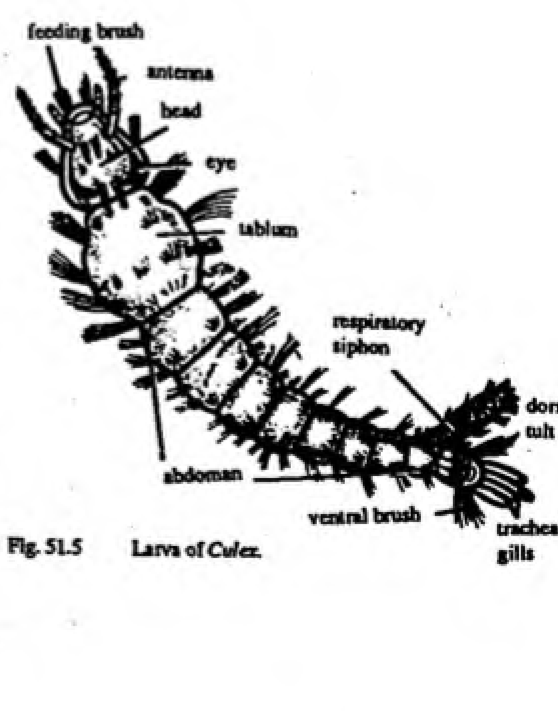


Fig. 51.5 Larva of *Culex*.

The mouth parts include labrum, toothed mandibles, flatenned maxillae, labial plates and two dense mouth brushed. The larva, thus, subsists on solid food. The thorax is unsegmented but bears three lateral pairs of unjointed tubercles, each bearing a tuft of bristles. The abdomen comprises nine segments, each bearing a tuft of bristles. The 8th segment bears a long, tubular, chitinous respiratory siphon. The siphon bears a *comb* of very small scales at the base 2 large hair tuft and two rows of flatenned spines called *pecten*. At the tip of the siphon there are two *spiracles* leading into the tracheae. Around the spiracles are five leaf-like lobes which can close over the spiracles to prevent water from entering. The respiratory system is *metapneustic* in which only the last pair of abdominal spiracle is open. At the end of the 9th segment is an anus surrounded by four leaf-like *tracheal gills*. The tracheal gills bear tracheae instead of blood vessels. The 9th segment bears a tuft of *dorsal bristles* at its tip and ventrally a bushy tuft of bristle called *ventral brush*.

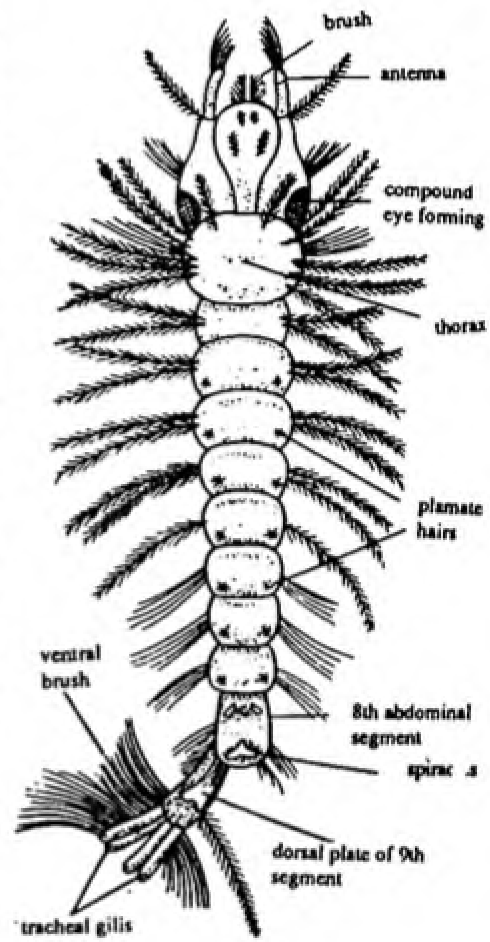


Fig. 51.6 Larva of *Anopheles*.

The larva a *Anopheles* is without a respiratory siphon instead the 8th segment bears a raised chitinous quadrilateral plate with two spiracles. The spiracles are surrounded by five small leaf like flaps. Near the spiracles, there are small bristles which form a pair of *pecten*. *Comb* is absent. The larva has *palmate bristles* or *hairs* forming a pair of tufts on each thoracic and most of the abdominal segments. A palmate bristle consists of a short stalk from which a number of slender and flat leaflets tradiate. In *Anopheles* the larva can breathe and feed lying parallel with the surface of water surface as in *Culex* it floats in water obliquely with head lowermost.

During this period the larva moults for four times. A full grown larva is about 12 mm long.

3. Pupa. After the last moult, the larva becomes pupa. This is the resting stage. The pupa has a large rounded anterior part consisting of the head, thorax and a slender, bent posterior abdomen. Thus it is comma-shaped. It floats in water with the cephalothorax uppermost and the abdomen curved beneath it. On the mid-dorsal side of the cephalothorax is a pair of tubular *respiratory trumpets* which are broader at the distal end. They communicate with an anterior pair of thoracic spiracles. It swims actively with a pair of large, chitinous and leaf-like *paddles* or *fins*. The pupa is unable to feed. It flutters up and down in water when disturbed, hence, it is called a *tumbler*.

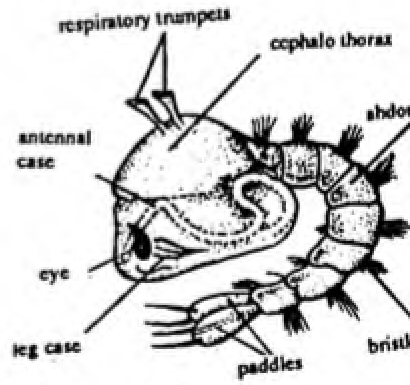
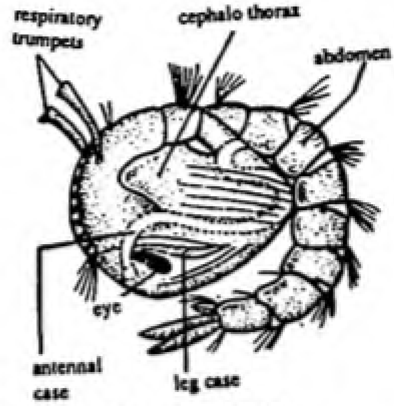


Fig. 51.7 Pupa of *Culex*.

In the pupa of *Anopheles* the respiratory trumpets are short and broad and the abdomen is more strongly curved than that of pupa of *Culex*.

The pupal period last for 1 to 3 days. On this period the pupa is transformed into a complete adult. Most of the larval organs in the pupa are broken down. The process of breaking down and disintegration of larval organs is called *histolysis*. The adult organs are formed. For the formation of adult organs groups of formative cells are formed. For the formation of adult organs groups of formative cells are set aside in the larva, they are called *histoblasts* or *imaginal buds*. This process is called *histogenesis*. Through the transparent skin of the pupa, the adult organs, such as compound eyes, antennae, wings and legs are visible.

4. Imago. The pupal stage lasts for a short duration, usually of two or three days. After the completion of metamorphosis, the pupa is transformed into the perfect adult insect, called *imago*. The pupal skin now splits along the back between the two respiratory trumpets. The imago emerges out with well-developed wings and after a few moments flies away.



7.8. Pupa of *Anopheles*.

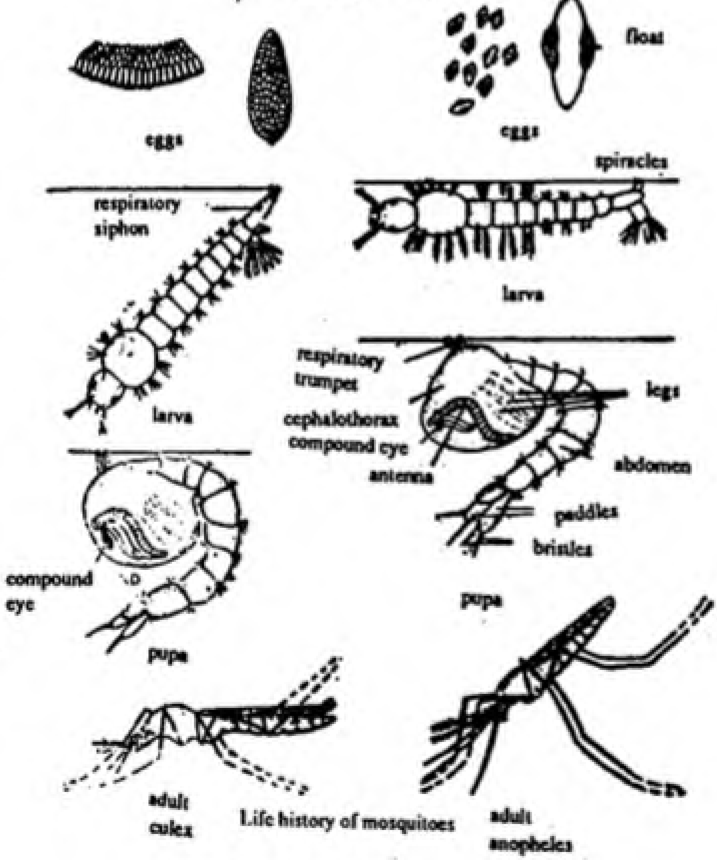


Fig. 51.8 Life history of *Mosquitoes*.

The complete life cycle, from egg to adult, takes from ten to several days. The female lives for one month or more and the male for about a week.

Table showing differences between the life history of *Culex*, *Anopheles* and *Aedes*.

Culex	*Anopheles*	*Aedes*
I. Eggs		
1. Eggs are laid on the surface of water in a mass called the egg-raft.	1. Eggs are laid singly on the surface of water.	1. Eggs are laid singly in moist soil and hatch when flooded
2. Eggs are cigar shaped and lack floats.	2. Eggs are boat shaped. Each has a pair of lateral float	2. Eggs are spindle shaped and lack floats.
3. Eggs lie vertically in the raft.	3. Eggs float horizontally on the surface of water.	3.
4. Number of eggs laid at a time varies from 200 to 300.	4. Number of eggs laid at a time varies from 40 to 100.	4. Number of eggs laid at a time varies from 200 to 400.
II. Larva		
5. Larva floats in water obliquely with the head lowermost.	5. Larva floats horizontally on the surface of water.	5. Larva floats in water obliquely with head lowermost.
6. Without palmate hair.	6. With palmate hairs on abdomen.	6. Without palmate hair.
7. Larva bears a long, tubular, chitinous respiratory siphon on the 8th abdominal segment for breathing air. The siphon bears more than one pair of hair tufts.	7. Larva has, on the 8th abdominal segment, a rised chitinous plate bearing two spiracles for breathing air.	7. Larva has a respiratory siphon that is relatively short and stout and bears only one pair of hair tufts.
III. Pupa		
8. Pupa bears long respiratory siphons on the cephalothorax.	8. Pupa bears relatively short and broad respiratory siphons on the cephalothorax.	8. Pupa bears long respiratory siphons on the cephalothorax.
9. It is colourless.	9. It is greenish.	9. Pupa is colourless.
10. Each paddle bears a single long bristle.	10. Each paddle bears one long and one short bristle.	10. As in *Culex*
IV Imago		
11. Greyish body.	11. Greyish hairy body.	11. Greyish black body.
12. Wings lack dark spots.	12. Wings have dark spots.	12. Wings are without spots.
13. Imago rests with the body parallel to the surface. Body hump-backed when at rest.	13. Imago rests with the body making an acute angle with the surface. Body is not hump-backed when at rest.	13. Imago rests with the body parallel to the surface. Body is hump-backed when at rest.
14. Proboscis is bent downward, when imago is at rest.	14. Proboscis is in line with the body, when imago is at rest.	14. Proboscis is bent down when the imago is at rest.
15. Abdomen bears scales on the sterna.	15. Abdominal sterna lack scales.	15.
16. Maxillary palps are short in the female and longer than proboscis in the male but not clubbed.	16. Maxillary palps are as long as proboscis in both sexes and clubbed in the male.	16. Maxillary palps are short in the female and longer than the proboscis in the male but not clubbed.
17. Scutellum is trilobes.	17. Scutellum is evenly rounded.	17. Scutellum is trilobed.
18. Thorax is without markings.	18. Thorax lacks markings.	18. Thorax has silvery or white markings.
19. Tip of abdomen of female is blunt with cerci retracted.	19. Tip of abdomen of female is blunt with cerci retracted.	19. Tip of the abdomen of the female is poined with cerci protruding.
20. Spreads filariasis and encephalitis.	20. Spreads malaria.	20. Spreads yellow fever and dengue.

ECONOMIC IMPORTANCE

The mosquitoes are definit nuisence as they inflict painful and irritating bites besides sucking blood. Most of them act as transmitting agents or vectors for some diseases of man and other animals. The diseases caused by mosquitoes in man are malaria, yellow fever, filariasis, dengue, encephalities, leprosy etc.

(i) *Malaria.* Malaria a deadly human disease. It is caused by a protozoan, *Plasmodium.* It is transmitted by female *Anopheles.* In malaria there is high recurring fever accomplished by chills and shivering.

(ii) *Yellow fever.* Yellow fever is confined to Africa and south America. It is caused by a virus and the vector is *Aedes aegypti.* The symptoms include high fever, internal bleeding, severe headache, and pains in the bones, anaemia, severe jaundice and

vomitting of blood and bile occur.

(iii) *Filariasis*. Filariasis is caused by a helminth parasite, *Wuchereria bancrofti*. Its vector is *Culex fatigans*. The disease begins with a slow inflammatory swelling of limbs, scrotum or mammae. Filariasis may eventually cause *Elephantiasis*, if left unattended.

(iv) *Dengue*. Also called back bone fever is caused by a virus and is carried by *Culex fatigans* and *Aedes aegyti*. The symptoms are sudden high fever with rash on the face and severe headache, pain in muscles and joints etc.

(v) *Encephalitis*. Encephalitis is caused by a virus and is spread by various species of *Culex* and *Aedes*. The symptoms are headache, high fever, drowziness and inflammation of brain.

(vi) *Leprosy*. According to the scientists of JIPMER, leprosy can be spread by mosquitoes.

(vii) *Dermatobia*. Dermatobia is a disease of the skin of man and cattles of central and south America. *Psorophora*, a mosquito, carries the eggs of a bot-fly, *Dermatobia* (as it lays egg on the body of mosquito). When the mosquito bites, the eggs of botfly quickly on the human skin and the larvae penetrate the skin causing swelling and cutaneous myasis.

Control of Mosquitoes

Following general methods may be used for the control of mosquitoes:

1. *Elemination of breeding places*. The larvae and pupae develop in the water, therefore, elemination of breeding places in important. Small ponds, ditches etc. can be filled up with mud. Stagnant water, swampy areas, marshes must be drained of. Water should not be allowed to be stored in open cans, barrels, buckets etc. Bushes, shrubs etc. should be cleared.

2. *Destruction of larvae and pupae*. It is easier to kill the aquatic larvae and pupae than the adults. It can be done by spreading over water surface with crude oil, kerosine oil, etc.. Oil emulsions of DDT, BHC etc. are efective larvicides. Biological methods can also be employed such as larvicidal fishes like *Gambusia, Guppy, trouts, sticklebacks* etc. can be introduced in the water reservoir. Aquatic insectivorous plants, such as bladderwort (*Utricularia*) can also devour the larvae and pupae of mosquitoes.

3. *Destruction of adult mosquitoes*. This can be done by hands, traps fumigation, spraying etc. Fumigation with tarcamphor, cresol, sulphur or other derivatives of neptha burn to produce poisonous smoke which kill the adults. Spraying with DDT, gammexane, melathione etc. remain effective.

4. *Sterlization*. Sterlization of mosquitoes in Japan has been successfully done.

5. *Personnel protection*. It can be done by; (i) The exposed parts of the body may be protected by the use of gloves, soxes, boots etc. (ii) Use mosquito repellents like odomos, mustard oil etc. (iii) Mosquito nets should be used, especially at night (iv) The house should be built on a high grounds with proper drainage.

APIS (HONEY BEE)

Apis is a social insect living in colonies, build by themselves. A colony may have more than 50,000 individuals. They are semi- tropical insects that have adapted themselves in temperate climates, where they survive cold weather by forming themselves into winter balls within the hive.

There are five well recognized types of bees found in the world.

(i) *Apis dorseta* (Rock bee)

(ii) *Apis florea* (Little bee)

(iii) *Apis indica* (India bee)

(iv) *Apis adamsoni* (African bee)

(v) *Apis mellifica* (European bee)

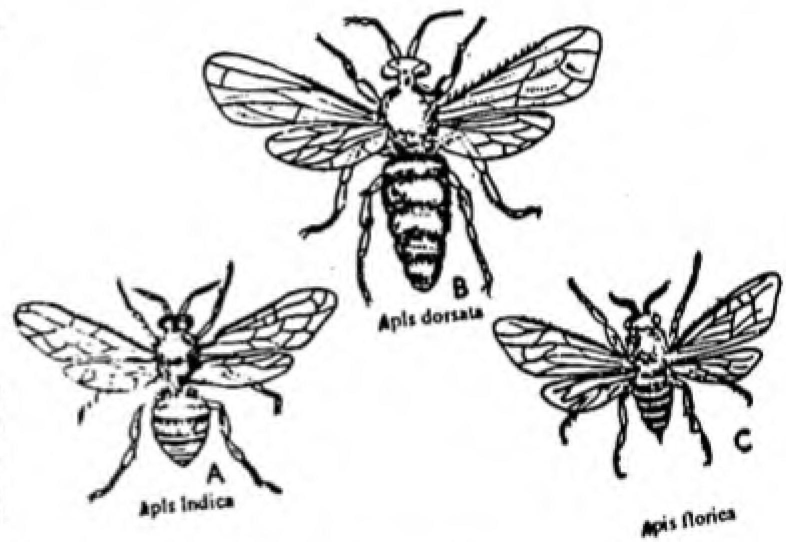


Fig. 52.1 Workers of three species of *honey bee*.

Out of these, three are common in India. They are *A. dorseta*, *A. florea* and *A. indica*. A. dorseta is the largest variety with average size of about 20 mm. It builds large comb on tree branches, high buildings etc. These are migratory species as during June and July they swarm to the hills, but in winter they come back. The workers build a fresh comb every time. A single comb may yield 60 pound of honey per year.

A. florea is a minature of the rock bee. It is a plain species and builds small comb on the tree branches, in bushes etc. They yield hardly a few ounce of honey per comb per year.

A. indica is of commonest occurance on the plain and forests. It builds several parallel combs in protected places like hollow of trees, caves, in rocks etc. The average output of honey is 6-7 pounds per colony per year.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endopterygota
Order	-	Hymenoptera
Genus	-	*Apis*

Castes of honey bee

The nest of honey bee is known as bee-hive. A hive in summer consists of 32 - 50 thousand or more individuals. A colony

may be weak or strong according to the number of worker bees. In a colony there are three types of individuals namely the queen, workers and drone. Due to the existence of several morphological forms, bees are said to be polymorhpic species.

Structure of worker bee

The worker is the smallest member of the colony. Its body is densely covered with hairs. The colour is usually brown or black bearing several peculiar structures which helps in the collection of pollen and nectar from the flowers.

The body is divisible into:

1. Head.
2. Thorax.
3. Abdomen.

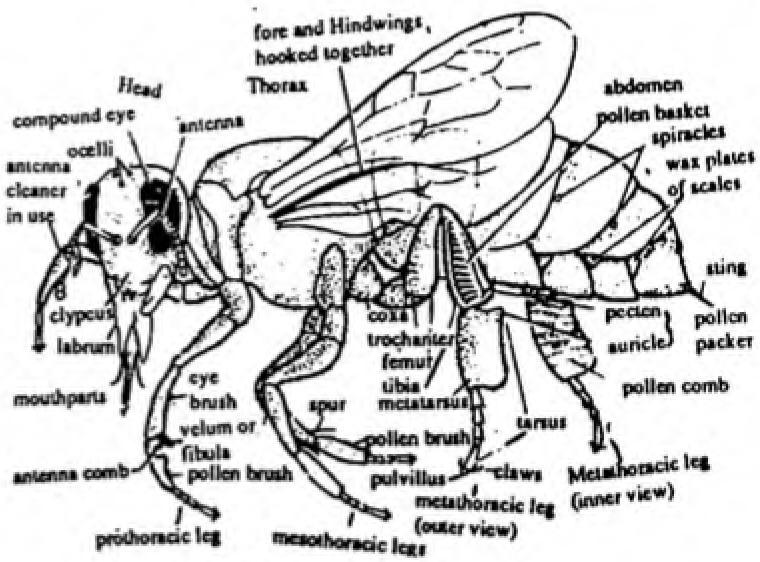


Fig. 52.2 Worker bee in lateral view.

1. Head. The head is flatenned triangular widest cross-wise through the upper corners, which are capped by the large compound eyes. The compound eyes are present on dorso-lateral sides of the head. Each eye has several ommatidia (4900 in queen, 6300 in worker and 13000 in drones). Three ocelli are present in the middle of the face. The autennae are many - jointed and inserted in the middle of the head. They have many olfactory pits that provide a keen sense of small.

Mouth parts. The mouth parts attached to the lower part of the head and are of chewing and lapping type. These are modified for collecting the nectar and the pollen. Mouth parts consist of *labrum, epipharynx, mandibles, maxillae* and *labium*. Labrum lies below the clypeus, below the labrum is fleshy epipharynx which is an organ of taste. At the sides of labrum are the two heavy mandibles which work sidewise. In the workers they are spoon-shaped as they lie, but they are sharp, pointed and toothed in the queen and drone. The function of mandibles are to mould wax and manipulating the pollen. In the maxilla, lacina is absent while maxillary palps are vestigial and the *glaea* is elongated and blade like. In the labium, the *paraglossae* are very much reduced and *glossae* are very much elongated. They are united, hairy and form a honey-spoon or labellum at the termination. The labial palps are well developed and they help to make the ligula up. The whole apparatus is protected the galeae of maxillae. When the bee sucks up nector, the terminal lobes of labium and maxillae are pressed close together as to make a tube between them. The food is then taken in by a sucking action of the pharynx. At the tip of the tongue these occurs labella and there is a groove running along the entire length on the ventral side, within the tongue this groove extends into a double barrel tube. A flexible chitinous rod lies along the back wall of this channel which is itself provided with a still finer groove along its ventral surface.

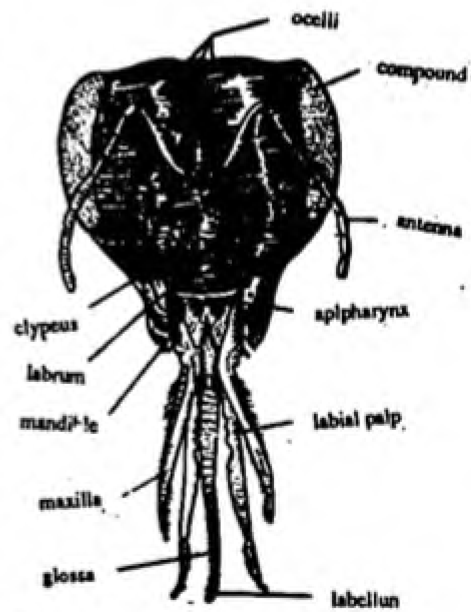


Fig. 52.3 *Apis.* Head.

2. Thorax. The thorax is large and strong. It bears two pairs of wings and three pairs of legs.

The wings are small, narrow, membranous and transparent. They lie flat over the back at rest. They have a much modified and reduced venation. The fore- and hind-wings of each side are interlocked by hooks held in a groove, so as to work together during flight. Wings may vibrate over 400 times per second during flight. A worker is capable of long flight, even 12 km.

There are three pairs of legs, which are densely covered with hairs. The forelegs are called prothoracic, mid-legs as mesothoracic and hind legs are metathoracic. Each leg consists of five parts, coxa, torchanter, femur, tibia and tarsus. The tarsus is five jointed and terminating into the claws and pulvillus.

(i) *Prothoracic legs.* Tibia of the fore-legs possesses distally at its anterior face a number of stiff bristles which forms pollen brush. From its posterior face there is also found a movable plate-like process or velum, which fits over a circular notch in the upper part of the first tarsal segment. The velum and antenna-comb together serve as antenna cleaners. On the anterior surface of the first tarsal segment there are also some bristles which are termed as eye-brushes and serve to remove particles and pollen from the outer surface of the compound eyes.

(ii) *Mesothoracic leg.* The midleg has all the segments as seen in the foreleg. The tibia bears a brush on its inner surface and a spine-like pollen-spur on its distal end. The spurs of both the midlegs are used to remove pollen from the pollen baskets of hindlegs and to disloge wax from wax pockets on the ventral surface of the abdomen.

(iii) *Matathoracic legs.* Each metathoracic leg has a large tibia with a cavity with bristles forming a *pollen basket* or *corbicula* used for storing pollen during collection, at the distal end the tibia has a row of stiff bristles called *pecten* below which is a flat plate, the *auricle*. The pecten and auricle form a pollen packer to convey pack pollen into the pollen basket.

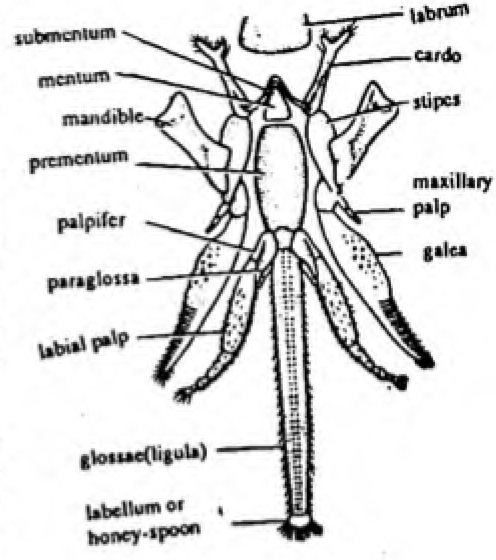


Fig. 52.4 *Apis.* Mouth parts.

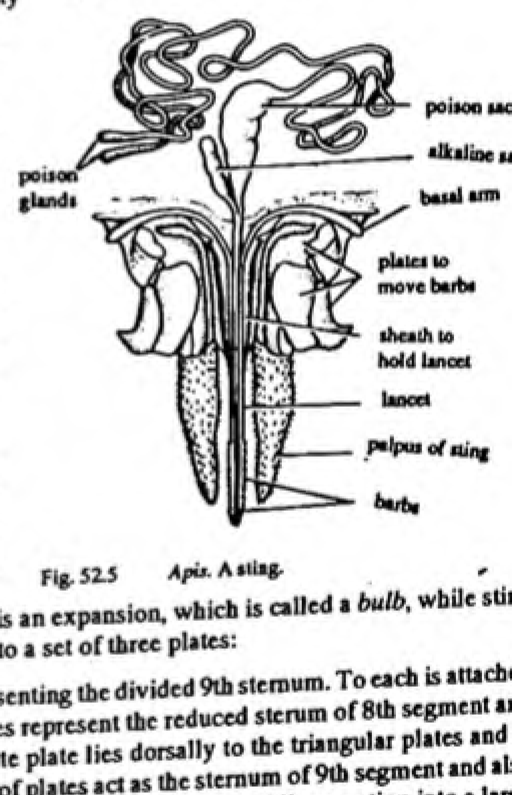


Fig. 52.5 *Apis.* A sting.

3. Abdomen. The abdomen is oval and less hairy than the rest of the body. It bears six distinct segments. It possesses wax glands and sting.

(i) *Wax glands.* The glandular area secreting wax lies on the ventral surface of the last four visible segments of the abdomen. The wax is secreted through minute pores in the form of flat scales. The wax is masticated by the mandibles before it is used for building the cells of the honeycomb.

(ii) *Sting or terebra.* In the worker bee, ovipositor changes so as to take the function of sting, which for injecting poison. The actual sting or terbera consists of a central poison-canal enclosed by a stylet sheath and two ventral stylets or lancelets. Stylets are grooved on dorsals side and form two ventral guide sails. The distal free termination of stylet and sheath are covered by spines or barbs. At the base, there is an expansion, which is called a *bulb*, while sting is continued into a pair of lateral basal arms. The string is attached to a set of three plates:

(a) The inner most pair is that oblong plate posterior in position and representing the divided 9th sternum. To each is attached the basal arm of the style sheath of its side. (b) Two triangular or fulcral plates represent the reduced sterum of 8th segment and to each is attached the corresponding arm of the stylet. (c) The large quadrate plate lies dorsally to the triangular plates and at the posterior angle. It represents the sternum of 9th segment these three pairs of plates act as the sternum of 9th segment and also function as levers. Two glands are also associated with the sting. A filiform poison gland pours its acidic secretion into a large poison-sac, which discharges its contents into the bulb. There is also an alkaline gland, which opens separately into the sting bulb.

Structure of Queen

The queen is 15-20 mm long. It is similar to the worker except elongated, tapering abdomen, short legs, small wings, short mouth parts and an ovipositor which serves for egg laying. The reproductive organs are well developed. The wax glands and the

pollen collecting apparatus are absent. The life-span of a queen is 2-5 years and during this span is lays 1.5 million eggs.

Structure of Drone

A drone is 15-17 mm long and stouter than worker. It has holoptic eyes which touch each other dorsally. The wings are powerful and the abdomen is truncate. It lacks wax glands, pollen collecting apparatus and the sting. The 9th sternum has two claspers and a membranous aedegus. The drones are developed parthenogenetically, in a large special cell of the hive. Their number is less in the hive sometimes only one drone in a hive.

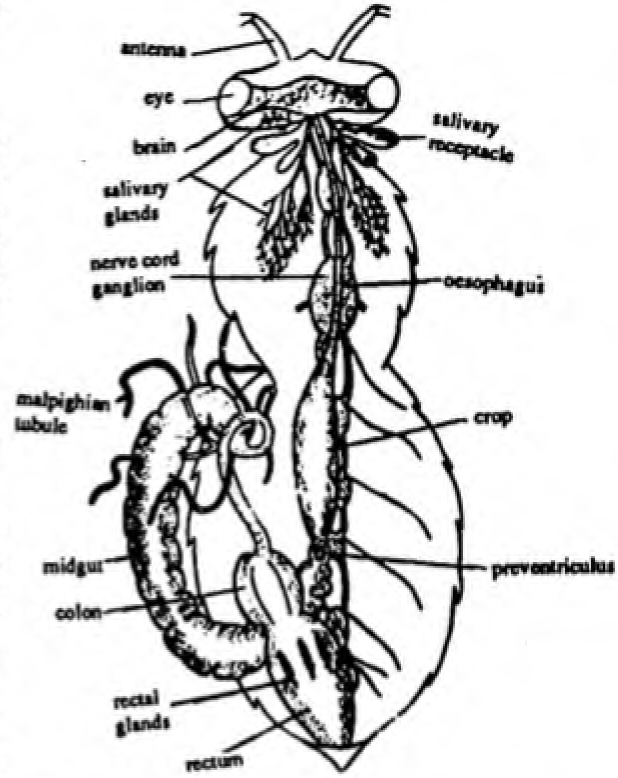


Fig. 52.6 *Apis*. Digestive and nervous systems.

DIGESTIVE SYSTEM

The digestive system includes alimentary canal and digestive glands.

The alimentary canal comprises a mouth which opens into the pharynx. Pharynx is a muscular widened tube that opens into long slender oesophagus. The oesophagus running clear through the thorax and open into an enlarged, thin walled sac, the crop or honey sac. The honey sac lies in the abdomen and it narrows posteriorly and opens into the stomach. The honey sac is of special interest in worker. The nectar collected from the flowers is held in it. From the sac the necter is regurgitated into the cells of the comb or given up first to another bee. The upper end of the stomach sticks up into the lower end of the honey sac as a small cone with an 'x' shaped valve in the summit. This opening is called stomach mouth and is guarded by four lips that take whenever food the stomach requires from the honey sac. Stomach leads into small intestine having a circlet of 100-125 slender Malpighian tubules. Intestine opens into terminal part of alimentary canal, the rectum which opens out through anus.

The salivary glands are located on the back of the head in the front part of the thorax and open upon the upper part of the labium.

CIRCULATORY SYSTEM

It is similar to that present in cockroach. The heart is consists of four chambers instead of 13 chambered heart of cockroach.

RESPIRATORY SYSTEM

The respiration is brought by the tracheal system as found in other insects. In all there are 10 pairs of spiracles present in thorax and abdomen. Two lateral tracheal trunks are enlarged in abdomen to form air sacs.

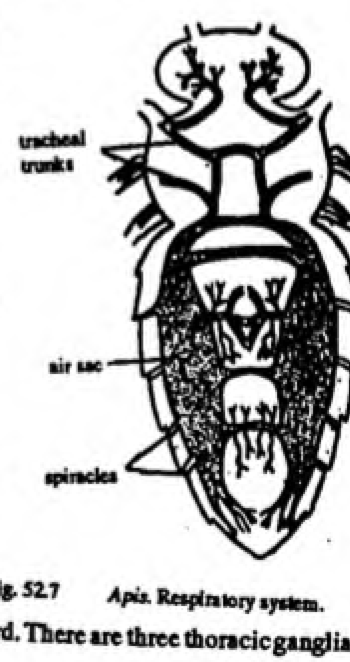


Fig. 52.7 *Apis*. Respiratory system.

NERVOUS SYSTEM

It is made up of brain, circum oesophageal connectives with double ganglionated nerve cord. There are three thoracic ganglia. Last two are fused. 5 - abdominal ganglia are also fused in a mass.

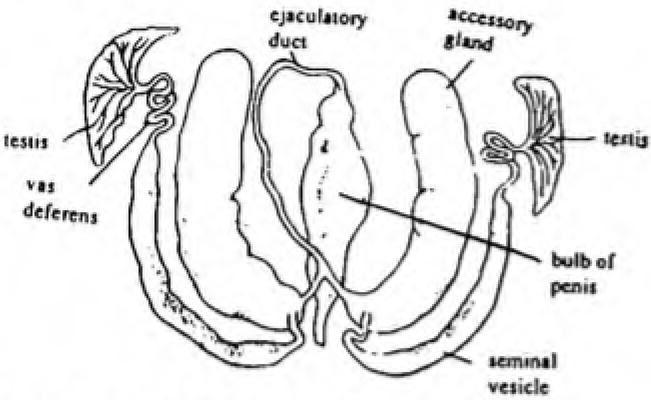


Fig. 52.8 *Apis*. Male reproductive organs.

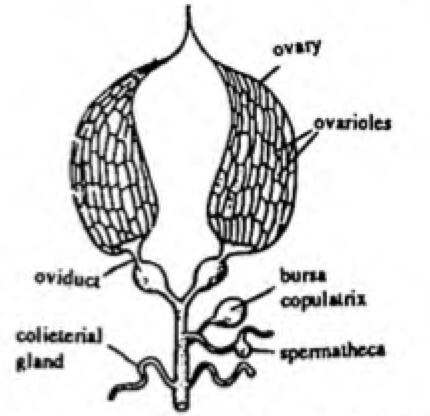


Fig. 52.9 *Apis*. Female reproductive system.

The Sexes are separate. The male reproductive organs comprise a pair of testes. Each testis is enclosed in a double mebrane and consists of 250-300 seminiferous tubules. From each testis arises a vas deferens. The vasa deferentia enlarge to form seminal vesicles which are usually cylindrical or sac-like in appearance. The two ejaculatory ducts leaving the vesicles are rudimentary and the accessory glands open into the common ejaculatory duct.

The female reproductive organs include a pair of ovaries. Each ovary bears numerous ovarioles. From each ovary arises an oviduct. The two oviducts unite to form the vagina which dilates posteriorly to form bursa copulatrix. A median spermatheca is present together with a pair of collaterial glands which open into the spermatheca.

LIFE HISTORY

The life-history of honey bee can be studied under following heads:

Swarming. Over crowding in the hive leads to swarming. A large number of bees come out of the hive during the spring or early summer.

On the fine forenoon, the old queen leaves the hive to establish a new one, accompanied by a large number of old workers and drones. Left behind in the hive are the young workers and several new queens still in their cells but approaching the time of emergence. Only one queen survives by stinging to death the other newly-hatched queens.

Supersedure. In supersedure the old queen with reduced egg laying capacity is replaced by a new, young and vigorous queen. The old and new queen may continue to live together or the old one may be dragged. Under unfavourable conditions or due to certain enemies the entire colony of bees migrates to a suitable place. The migration of the entire colony is known as *absconding*.

Nuptial Flight About a week after emergence, the new queen takes her first aerial flight followed by a swarm of drones. The queen flies very high and the drones gradually drop out of the race. The last drone left in the race, mates with her. Mating occurs in mid-air, during which the queen receives spermatophores from the drone. The sperms are stored in spermatheca or sperm-reservoir of the queen to fertilize her eggs as long as she lives. The prime swarm is led by the old queen while

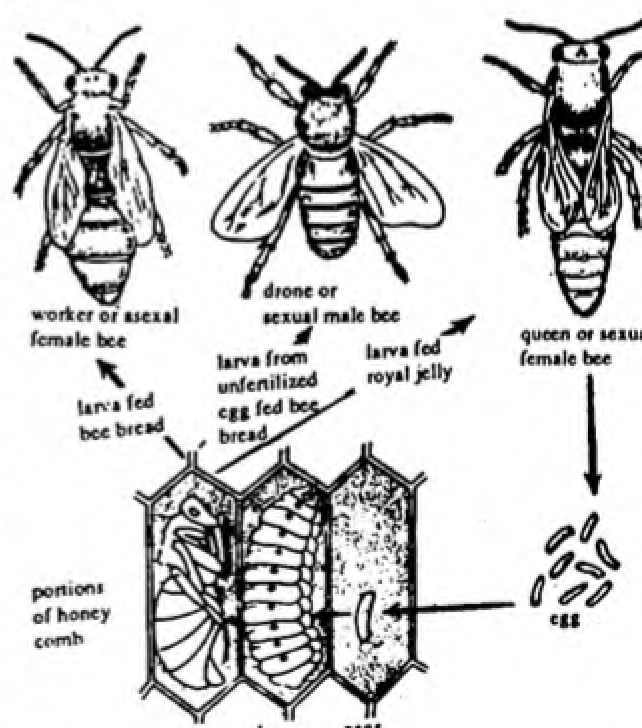


Fig. 52.10 *Apis*. Life cycle.

the second swarm is accompanied by the newly-emerged virgin queen.

The queen after mating returns to the hive and does not leave it till become old. It was thought that a queen mated only once in its life. But it has now been known that out of experimented 110 queens, about 55 mated twice. This experiment was carried out very successfully in U.S.A.

After the swarming period the remaining drones are pushed out of the hive by the workers, if they survive.

Eggs and Egg-laying. Egg laying starts 3 days after copulation. The eggs are of two types-fertilized eggs developing into queens and workers and haploid eggs developing into drones, and are laid into separate chambers or cells. The fertilized eggs are laid into workers or queen cells, while the unfertilized into drone cells. In a season of abundant nectar, the queen lays upto 1000 eggs per day. The eggs are elongated and pinkish and are attached to the bottom of cells.

Larvae. After three days a tiny larva or *grub* is formed from each egg. There are no eyes and legs in the larva. For the first day all larval are fed on 'royal jelly' which is secreted by pharyngeal glands of young workers. Afterwards, larvae of the drones and workers are fed on honey and pollen, but the larvae of queen are continuously fed on 'royal jelly'. In this way the food-supply causes them to develop differently. After several moults the larva grows, then its cells sealed with a wax-cap.

Pupa. The larva changes into a pupa in the sealed chamber.

The wax-lid is porous and allows exchange of air for respiration. The pupa secretes a thin silken cocoon around itself and undergoes metamorphosis. It involves a change of legless, wingless and eyeless worm-like creature into a winged insect with legs and eyes. After the pupal period is over, the lid closing the cell is cut off by the young bee with jaws to become free.

The time of development for each caste is different which can be shown as:

Caste	*Egg*	*Larva*	*Pupa*	*Total*
1. Queen	3 days	5 1/3 days	7 days	15 1/2 days
2. Worker	3"	5"	13"	21"
3. Drone	3"	6"	15"	24"

The queen produced from her mandibular gland a special secretion called queen substance. It is picked up directly by a few workers that are in contact with the queen. These workers spread it to the other. The "queen substance" inhibits the workers from building brood cells for new queens.

The freshly emerged workers are first entrusted with the indoor duties for two to three weeks during which they act as nursing bees, dance attendance on the royalties, look after brood cells, build and repair the comb. Later on, they are put to outdoor duties and they are completely occupied in collection of nectar and pollen, guarding the hive, air conditioning, temperature regulation and ripening the honey, etc.

At the approach of winter, the drones are driven out of hive by the workers. They are either stung by workers or die of cold or hunger.

The queen and workers live there to pass over the unfavourable condition feeding over the stored honey and pollens. On the return of spring the activities are regained.

COMMUNICATION

The communication in insects is achieved by many ways such as visual stimuli, sound, chemical stimuli, body secretion etc. The honey been has surprised by their peculiar movement, better known as 'bee dance'. This peculiar sense of understanding and communication among bees has led *Carl Van Frisch* to be honoured with Noble Prize in 1973.

All the bees of a hive do not go out for the search of food. There are certain workers generally called foregers or scout bees who perform this duty and on their communication other bees move to the feeding place. These forgers collect the nector and

return back to the hive and communicate the source by performing the dance. The dance is performed in two manners, round dance and tail wagging dance. If the food source is less than 100 metres from the hive, it performs a circular dance. If the source is more than 100 metres, the dance performed is making a figure of 8.

The round dance convey the information about the source of food only where as the tail wagging dance indicates the source, distance, direction and the quantity of food. Between each semicircle, the bee moves along the vertical plane wagging its abdomen side to side. The frequency of wagging decreases with the increase of dance. The movement of sun has a definit relation with the direction of dance.

When forager performs its dance the other workers join the dance for a while and than leave the hive in the direction of food. *A. Wenner* (1964) claimed that foragers communicated to the other workers of their hive not only by their dance but also by producing peculiar sound which results due to the vibration of their wings. The intensity of sound is proportional to the distance of food from hive and also to the quantity of the food.

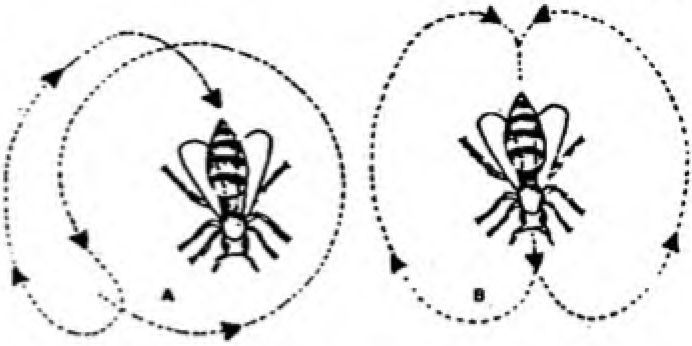


Fig. 52.11 Two different types of dances. A—*Round dance*, B—*Tail wagging dance*

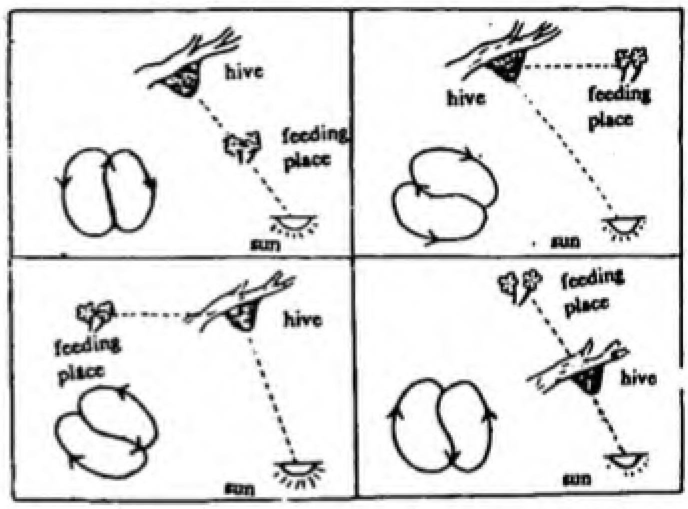


Fig. 52.12 Directional changes in *bee dance* to devote the feeding place with relation to the position of sun.

Structure Of A Hive

The highest degree of nest construction among insects is found in bees. The hive is generally built hanging from a building, rock or branch of tree. It consists of a thick vertical sheet bearing two layers of hexagonal chambers known as cells. The cells are of following types:

(i) ***Storage cells.*** These cells contain honey and pollen. These are generally built on the margin and at the top of the comb.

(ii) ***Brood cells.*** The brood cells contain young stages and are built in the centre and the lower part of the comb. The brood cells are further divided into three types:

(a) *Workers cells.* These are of the size of the storage cells and are used for rearing workers. They lie horizontally in the hive.

(b) *Drone cells.* These are about 6 mm. wide and are used for bringing up the drones. They are also horizontal in position.

(c) *Queen cells.* They are still larger and are used to rear the queens. They may be cylindrical or vase-like in form, and are vertical in position.

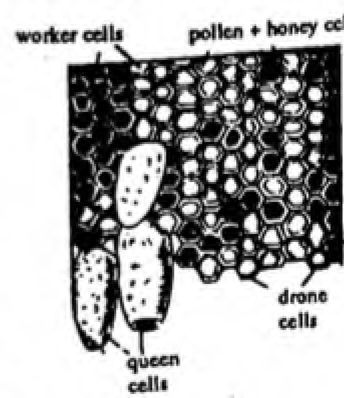


Fig. 52.13 *Bee hive.*

There are no special cells for adults, as they keep generally moving about on the surface of the comb or clustering cells which are situated on the upper part of the comb.

The wax used in building of a comb is secreted from the wax glands present in the abdomen of workers. This wax has a melting point of 140°F. Before use the wax is masticated and mixed with secretions of cephalic glands to convert into a plastic substance. The hive is polished with substance, *propolis*, prepared from pollen, is used for making the comb water proof.

ECONOMIC IMPORTANCE

Honey bees are most valuable domesticated animal of man and have been associated with human race from time of Vedas and Ramayana. They provide us honey and wax and more over they help in pollination.

Honey. The honey is used by man as the source of natural sweets for preparing cakes, breads etc. It has great food value as one pound of honey is equal to 4.5 pounds of grapes or 5 pounds of apples or 3.5 pounds of potato. It is also a very powerful tonic and can be easily compared to 365 UG - thiamin (Vitamin B1), 268 UG Riboflavin (G), 18 MG Ascorbic acid (C), 254 UG Pantothenic acid (B3) or 0.60 MG Nictonic acid (B3).

The chemical composition of one pound of honey is: 6 1/2 oz. Levulose (fruit-sugar), 5 1/2 oz. Dextrose (Glucose), 9 gm. Sucrose, 3 oz Moisture, 7 gm. Detrines and gums, 1 gm. of Fe, Ca, Na etc. and about 4% of undetermined sustance. The colour of the honey and chemical composition and flavour usually depend on the flowers visited by worker-bees.

Bee Wax. The wax is removed from the bee hives and is used in making polishes, candles, corbon papers, electrical and other products.

Pollination. Perhaps the greatest service of honey bee is the pollination of flowers of fruit plants and seed crops.

Bee venom. It is secreted by poison-glands of stings. It is transparent and, contains formic acid, histamine, tryptophane, sulphur, many proteins, volatile oils, enzyme etc. Clinically it is used in the treatment of rheumatism, keratoconjunctivitis, iritis, iridocylitis and in the control of blood pressure.

53

CIMEX (BEDBUG)

The bedbugs are domesticated insects and are intimately associated with man throughout the ages. They are sanguivorous as they suck the blood of man. Bed bug includes 30-40 species of wingless brownish blood sucking insects, mostly parasitic on birds and bats. Three species attack man these are *Cimex lectularius*, *C. hemipterus* and *C. boueti*. Out of these first and second are more common. The third one is found in Africa, Southern Asia and West Indies.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Hemiptera
Genus	-	*Cimex*

HABITS AND HABITAT

They are cosmopolitan in distribution. They inhabit dark, damp human dwellings like houses, hotels, rest-houses, barracks, etc. They live in cracks in the walls and floor, in crevices in the beds and furniture, under mattresses, carpets and wall paper, and in similar places.

The bedbug is a temporary ectoparasite of man feeding on the blood. They are nocturnal, but may come out during the day. A well fed bug can do without food for several months or even a year. The starving bug may reports to cannibalism. They are oviparous and undergo gradual metamorphosis. This bad smelling pest lives for 5-6 months.

MORPHOLOGY

Shape, Size and Colour. The body is oval, dorsoventrally flatenned, measuring about 5 mm in length and 3 mm in width. The colour of the body is brown becoming deep purple or red after it has fed.

Division of body. Like other insects, the body is divisible into three parts:

1. Head

2. Thorax

3. Abdomen

1. *Head.* The head is short, broad and fits into a notch of the prothorax. It bears a pair of compound eyes, 4 jointed antennae, and mouth parts. The simple eyes or ocelli are absent.

The mouthparts are of the piercing and sucking type and form a hollow beak or *proboscis* in front of the head. The beak is formed by the *labium*, which bears a middorsal groove for enclosing the four sylets of two mandibles and two maxillae. The saw like mandibular styles are used for making puncture in the skin whereas the maxillae for the inward flow of blood and downward flow of saliva. This is facilitated by two channels of the maxillae. The maxillary and labial palps are absent.

At rest, the rostrum is bend beneath the thorax but while feeding, it is pointed downwards or forward. The mandibular sylets make a puncture in the skin and the saliva runs down the puncture and prevents the clotting of blood.

2. *Thorax.* The thorax is made up of three segments prothorax, mesothorax and metathorax. Prothorax is very large. Its pronotum is notched anteriorly to receive the head. Mesothorax is very small. Metathorax is covered by a pair of vestigial fore-wings or *hemelytra* that arise from the mesothorax. There are no hind- wings. Each thoracic segments bears ventrally a pair of short, stout legs. The legs have 3-jointed tarsi and strong claws. Stink glands open on the ventral side of the metathorax.

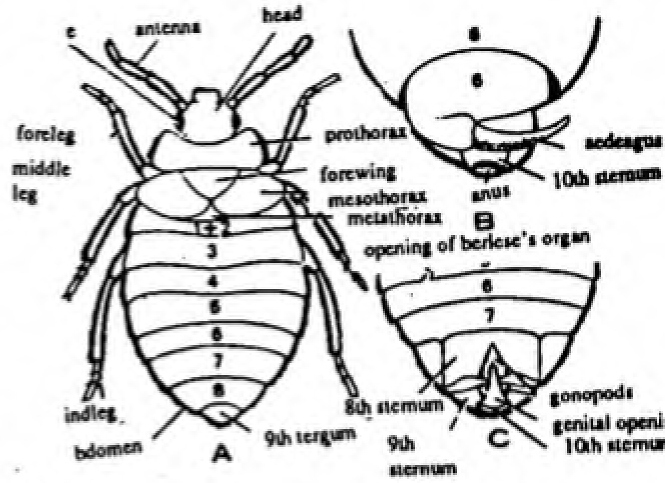


Fig. 53.1 *Climex.* A—Adult man, B—Genitalia of male of male, C—Posterior end of Female.

3. *Abdomen.* The abdomen is flat and made up of 7 segments. In the male, it is relat. ely narrow and pointed and ends in a curved hook-like clasper, which serves as a sheath for the aedagus or penis. In the female the abdomen is broad and rounded and has a prominent notch in the 4th sternum a little to the right of the middle line. The notch is the opening of a peculiar copulatory pouch, the organ of Berlese or spermatophagous organ the cells of which are thought to ingest and destroy the excess sperms.

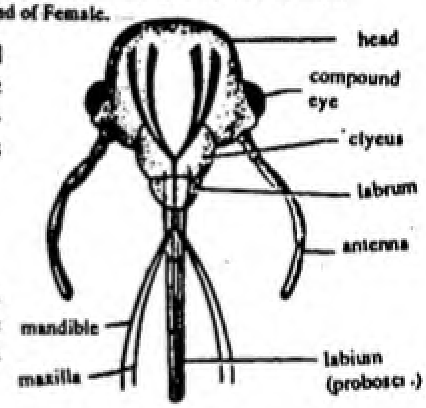


Fig. 53.2 *Climex.* Mouth parts.

LIFE HISTORY

Oviposition. After copulation the female lays eggs in holes, cracks, cervices etc. A female depositing 200 to 500 eggs in batch; the egg is 1 mm long, yellowish-white in colour, it is barrel-shaped with a raised lid at one end containing a micropyle; eggs are laid throughout the year in warm countries.

Nymph. In about 6 to 10 days duration the young bug or nymph hatches out of the egg by pushing off the lid. The nymph is about the size of a pin head and is semitransparent. In its general appearance, the nymph resembles the adult except that it is smaller and paler.

Few hours after hatching, the nymph becomes capable of piercing the host skin and sucking blood. It serches for man and feeds to its capacity in 3-4 minutes. It consumes blood three to four times of its own weight. If man is not available, it feeds on the blood of older bugs. After feeding it becomes rounded and bright red in colour. Now it settles down and in one to four weeks it moults into the 2nd stage nymph. The duration of 1st stage nymph depends upon temperature and other factors. The nymph undergoes five moults before changing into the adult. On the whole they take about 29 days to complete their like history. Therefore, the development of bed-bugs is direct, i.e. without metamorphosis.

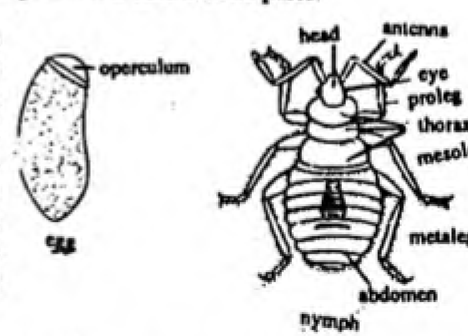


Fig. 53.3 *Climex.* Mouth parts.

ECONOMIC IMPORTANCE

The bedbug is a serious household pest. They feed on mammalian blood causing inflammation and irritation. This is due to the introduction of saliva into the human blood during feeding on it.

It is believed that the bedbug act as a transmitting agent of kala azar (caused by *Leishmania donovani*), relapsing fever

(spirochaetosis), typhoid etc. They however, do not cause the outbreak of these diseases in an epidemic form.

CONTROL

The best method, to control them, is the spray of DDT (5% in kerosene). This can be sprayed on all the walls and furniture where the bugs rest. Fumigation with sulphur, sprinkling boiling water, spraying of emulsion of kerosene, benzene and petrol and useful in reducing infestation bedbugs.

ENEMIS OF BEDBUGS

Bedbugs have many natural enemies. They are eaten by large bugs like *Reduvius*, a Mediterranean spider called *Thanatos*, small red house-ant (*Monomorium pharanis*) and pseudoscorpion *Chelifer*. Man also destroys them a large number.

54

TERMITES

Termites commonly called white-ants are social and polymorphic insects living in colonies. They have a well set caste system.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Exopterygota
Order	-	Isoptera
Type	-	Termites

HABITS AND HABITAT

The termites occur throughout the tropics and temperate countries. About 1600 species are known. The most common are *Microtermes* and *Odontoermes*. These are colonial insects. They either burrow in wood or make sub-terranean nests or *termitaria*. They feed mainly on wood and the cellulose is digested with the help of symbiont flagellate, *Trichonympha campanula* living in the intestine of termites.

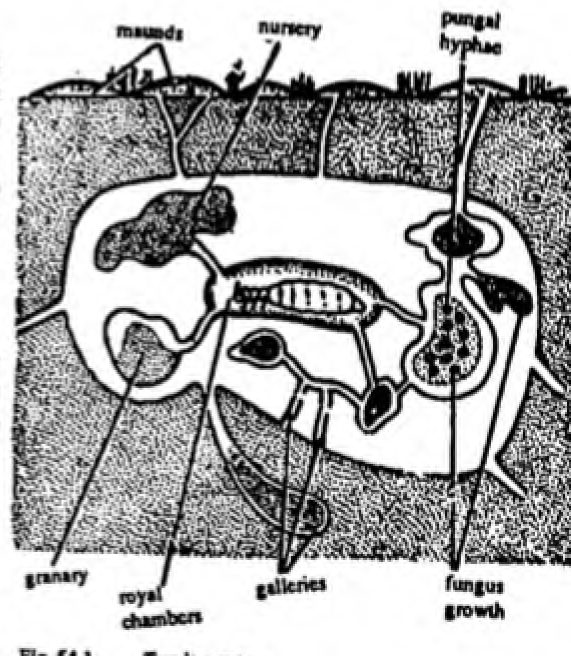


Fig. 54.1 *Termite nests.*

EXTERNAL FEATURES

These are soft-bodied small to medium sized insects. The colour of the body is white or pale yellow. The body is elongated and flatenned with smooth or hairy surface. The body is divisible into three parts.

1. Head

2. Thorax

3. Abdomen.

1. Head. The head is free and well selerotized. It bears a pair of short or long beaded antennae. The compound eyes may be well developed, vestigial or absent similarly ocelli may or may not be present. The mouth-parts are chewing type.

2. Thorax. It is divisible into three segments: prothorax, mesothorax and metathorax. Each segment bears a pair of legs on ventral side. Each leg with 4 or 5 jointed tarsus and a pair of claw. The fertile form bears two pairs of wings on the dorsolateral sides of mesothorax and metathorax. The wings are membranous and extend behind the body. They can be shed at basal suture. The wings are absent in sterile forms.

3. **Abdomen.** The abdomen bears 10 segments, ending in a pair of short 2-6 jointed cerci. In male the 9th segments bears a pair of anal styles.

Polymorphism

The termites are polymorphic and includes two forms:

1. Fertile caste or reproductive caste

2. Sterile caste

1. ***Fertile Caste.*** These are also called reproductive or sexual castes. The fertile individuals comprises the following forms:

(i) *Large winged or Macropterous forms.* These are true king and queen. Their colour is yellow, brown or black. The wings extend for beyond the hind-end of the body. The compound eyes are widely separated and are large. The ocelli are usually present. They live in royal chambers. The sole duty of king is to fertilize queen and queen is to lay eggs.

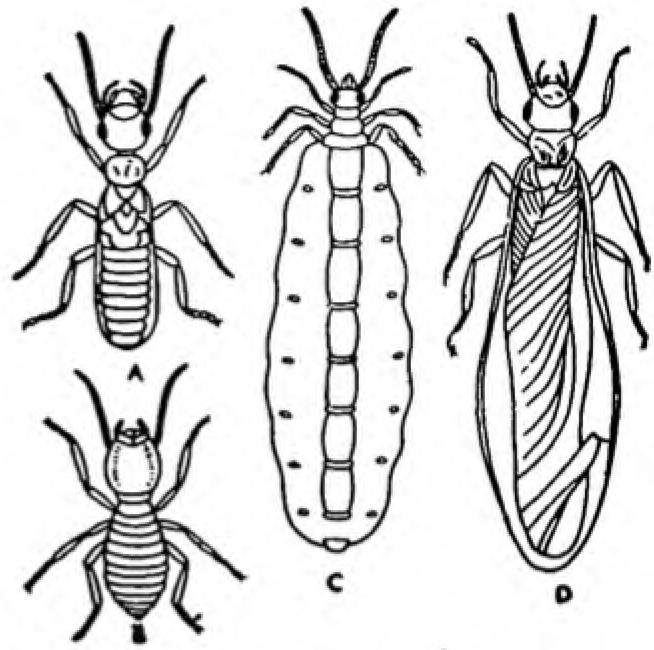


Fig. 54.2 A—Queen of *termites* without wings after nuptial; B—Wingless sterile worker, C—Mature queen, D—The winged male before nuptial.

(ii) *Short winged or Brachyterous forms.* These are supplimentary reproductive individuals. They have a less chitinized body of pale-yellow colour. The two pairs of wings are vestigial, short and stump-like. The compound eyes are small and the ocelli may or may not be present. These forms replace the true king and queen in case the king and queen die.

(iii) *Wingless or Apertous forms.* These are called ergatoid king and queen. Their structure is similar to that of a worker. Their body is colourless, wings are absent. The compound eyes are vestigial and the ocelli are absent. The sex organs are poorly developed.

2. ***Sterile Caste.*** These are wingless forms with rudimentary reproductive organs. These are blind or eyeless and colourless. The sterile caste is of three types:

(i) *Workers.* These are the most numerous of all castes. They are generally dimorphic, i.e., occur in two forms: small and large. In some cases they are trimorphic, being small, intermediate and large. The workers construct and repair the nest: collect and distribute the food: look after the eggs; and feed the nymphs, soldiers and the royal couples (true kings and queens). In some species, the workers cultivate a certain fungus on a finely chewed vegetable matter for feeding the

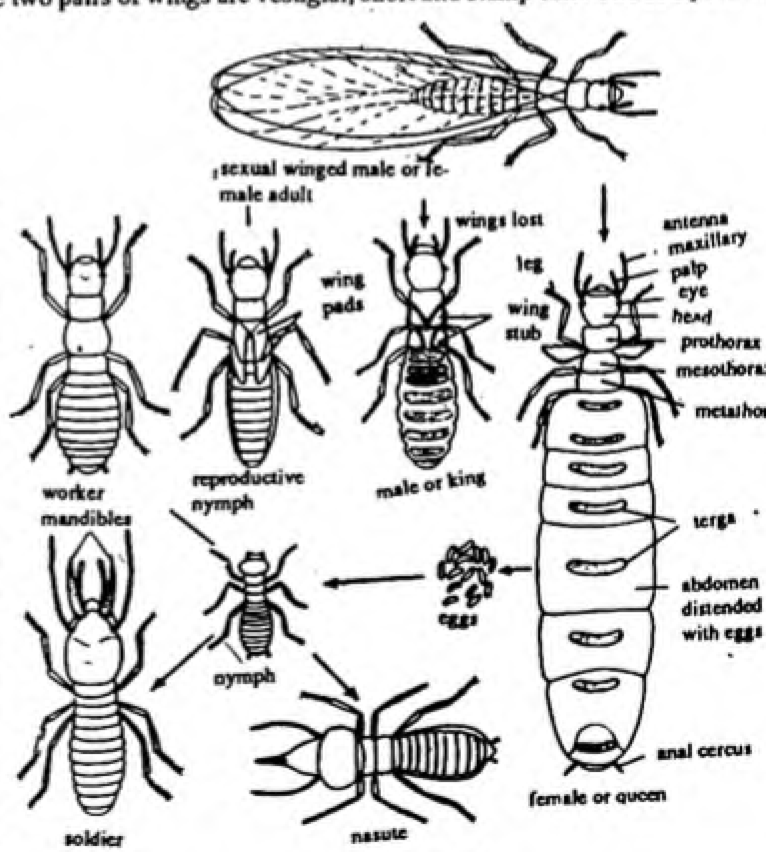


Fig. 54.3 Diffeent castes and life history of *Termite*.

royal couples and nymphs.

(ii) *Soldiers.* The soldiers are the most highly specialized. They defend the colony against enemies. These are pale coloured, pigmented forms with large chitinized big projecting mandibles. The brain is small and compound eyes are vestigial. In certain species there may be three grades of soldiers: large, medium and small sized.

(iii) *Nasutes.* In some higher genera the mandibulate soldiers are replaced by nasutes or *proboscideans.* These forms are short with vestigial mandibles. Their head is prolonged into a rostrum, which bears at its tip the opening of frontal gland. They throw a jet of sticky secretion of the frontal gland on the invaders through their rostrum. This secretion immobalizes or kill the enemy. The secretion is also used to dissolve hard substances like stones, concrete which are in the way of the workers when building. They may be dimorphic or trimorphic i.e. small, medium and large sized.

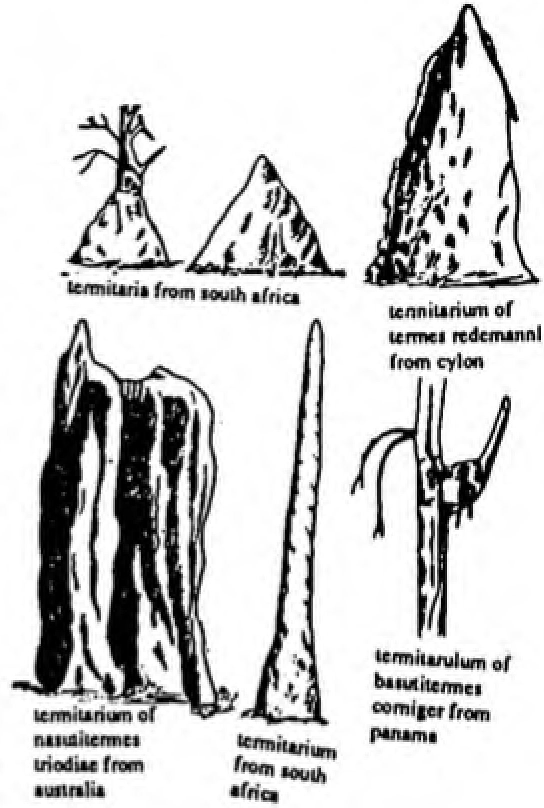


Fig. 54.4 *Termite nests.*

Nests

Primitive termites live in galleries bored in wood, logs, fense, poles, furniture etc. Some termites make tunnels in the ground, they destroy roots of grasses, vegetation and crops. Other construct a nest or termitarium. The nests consists of a labyrinth of irregular tunnels and chambers and may be entirely sub-terranean or with a mound above the surface. These mound may be from few metres to nine metres. The natives of Belgium and Congo clear them of the termites and use them as their dwelling huts. There are other types of the termites which form termitaria of cartn and masticated wood. These are of the size of a football and are placed upon the trees.

LIFE HISTORY

Swarming and mating. In the rainy season, with the first shower of rain, a large number of macropterous forms (kings and queens) leave the termitarium through the holes made by soldiers and fly away to new sites. It occurs during night or day depending upon the species. Mortality is very high during and after swarming. A large number of these forms are eaten up by lizards, birds, toads, ants etc. Only a few lucky ones survive and found a new colony. At the new site the king and queen mate. Thus the flight is not a true nuptial flight but rather a dispersal flight.

The king and queen together excavate a small burrow in the ground called the nuptial chamber. The queen lays eggs. These eggs are tended by the royal couple and hatch into workers, which soon take up their duties. The queen now undergoes drastic modifications. Her ovaries and fat bodies increase greatly while the jaw muscles degenerate. The king lives with the queen for life, and they mate at regular interval. The queen grows her abdomen to an enormous size, 50-75 mm. Her legs being absurdly small, she is unable of the slightest movements and she lies passively in the royal chamber. She is tended by the workers and defended by the soldiers. On an average she lays 4000 eggs per 24 hours. The queen may live for 6-15 years and lays about a million eggs during her life.

Development. The eggs are pale, smooth, oval or elongated. They hatch into wingless nymphs, and resemble adults excepts in size, wings are absent and sexually immature. After several moults the nymph reaches the adults stages. Formation of different castes from similar eggs in perhaps determined by variable food supply, hormones, pheromones, social beahaviours etc.

ECONOMIC IMPORTANCE

The termites are highly destructive insects. They attack and damage all sorts of plant materials, like wood used in buildings and bridges, furnitures, railway-sleepers, fences, crops, books and papers.

However, they are useful also in certain respects. They increase the fertility of the soil by making it porous with their burrows like the earthworms. They dispose off dead wood in the forests to make room for new vegetation. They are eaten by natives in some tropical countries, like South East Africa.

CONTROL

They can be destroyed in the field by pouring kerosine and cerbon bisulphide and chloroform or petrol. Nests can be fumigated by Arsenic, Sulphur and Kerosin oil. Trees must bee banded by coal- tar or 5% DDT emulsion in oil should be painted on the trunk to 0.45 metre from ground level. This treatment should be done after mansoons. A colony of termites can be eradicated only after findings out and killing the queen.

55

BOMBYX MORI

Bombyx mori commonly called as *Chinese* or *mulberry silkworm moth* is a native of China. It is well known for the pure silk. The moths are reared for silk.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Insecta
Subclass	-	Pterygota
Division	-	Endopterygota
Order	-	Lepidoptera
Genus	-	*Bombyx*
Species	-	*mori*

TYPES OF SILKWORMS

1. *Mulberry silkworm.* The mulberry worm (*Bombx mori*) belongs to the family Bombysidae. It produces most of the raw silk we use. This silk is supposed to be superior in quality to the other types due to its shining and creamy white colour. The caterpillar feeds on mulberry leaves.

2. *Tasar silkmoth.* A number of species of genus *Antherae* produce tasar silk. These are *A. mylitta, A. paphia, A. royeli, A. peryni* etc. Their caterpillar feed on leaves of Arjan, Asan, Sal, Oak and various other secondary food plants.

3. *Eri silkmoth.* The eri silk is produced by *Attacus ricini.* Their caterpiller feed an castor leaves. The silk is creamy white but is less shining.

4. *Munga silkworm.* The munga silk is obtained from the caterpillar of *Antheraea assama* which feeds an Champa, Cinnamon etc.

The mulberry silkmoth never occures in the wild state, it is completely domesticated. *Bombyx* is extensively cultivated all over the world and usually produces a single brood in a year i.e. *univoltine.* Some strain, however, produce 2-7 broods a year (*polyvoltine*) and are cultivated in warm climate.

EXTERNAL CHARACTERS

The adult moths are robust and cream white in colour with several lines across the fore wings. The body is very heavy and very hairy. It is about 25 mm long and has a wing expanse of 40-45 mm. Though both the pairs of wings are apparently well developed the moths fly very rarely. Females are longer than the males. The proboscis is absent, antennae are bipectinate or feathery in both the sexes. The life-span of adult is short usually ranging from 2-3 days. It does not take food during this period.

LIFE HISTORY

Male and female moths copulate in tail to tail position. Life-history comprises four stages.

1. Eggs

2. Larva

3. Pupa

4. Adult

The metamorphosis is complete.

1. **Egg.** Soon after fertilization, each female lays about 300-500 eggs in clusters upon the leaves of mulberry tree. They are fixed to leave with a gelatinous secretion. The eggs are small, smooth and spherical when laid they are yellowish white but become darker later on. The female dies within 3 or 4 days after egg laying. In the univoltine race overwritering takes place in the egg stage, as such the eggs may batch in months. In polyvoltine race the egg's batch in a few days.

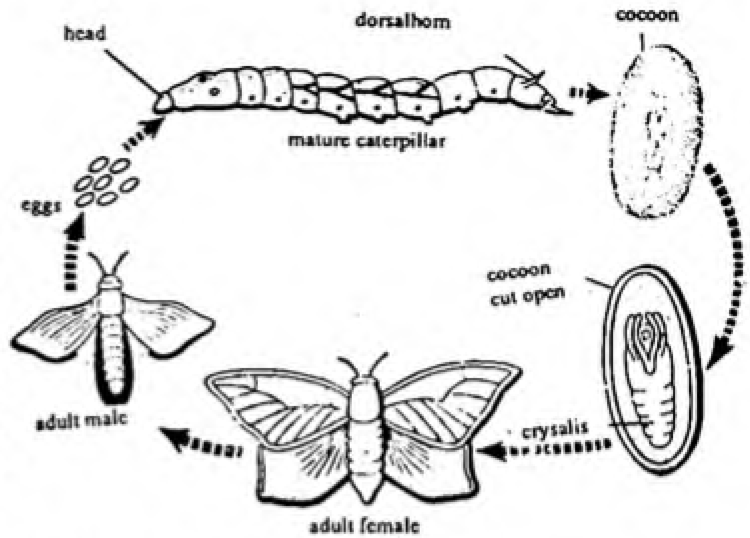


Fig. 55.1 *Bombyx mori*. Life history.

2. **Larva.** The larva is called *caterpillar or silkworm.* The caterpillar larva which batches from the egg measures 5-7 mm in length. These caterpillars move on the leaves in a characteristic looping manner. Their body is rough, wrinkled and greyish in colour. They are made up of 12 segments which are distinct into three parts: head, thorax and abdomen. The *head* bears mandibulate mouth parts with which they feed upon the leaves. The thorax is 3 segmented and all the segments bear a pair of true 5 jointed legs ventrally. The *abdomen* is 10 segmented and bears 5 pairs of unjointed, stempy *prolegs* or *pseudolegs.* These prolegs are present in each segment 3rd, 4th, 5th, 6th and 10th. A short dorsal *anal horn* is present on 8th segment. The prolegs of the last segment turn backwards to form the *claspers.* There is a row of small respiratory pores, the *spiracles*, on either side of the abdomen.

The larva has only three pairs of simple eyes or *ocelli.* The antennae, maxillae and labial palps are rudimentary.

The larvae feed voraciously upon the mulberry leaves and grow very quickly. They stop feeding, become inactive after 4-5 days, and than 1st moulting takes place. The 2nd stage larvae resemble the 1st stage larvae except that they are slightly bigger in size. They also eat voraciously for next seven days than 2nd moulting takes place and third stage larvae are formed. The larvae repeat this process for four times. The maturity is achived in about 45 days since the time of hatching. The matured caterpillar now measures 7-10 cm in length. By this time the formation of a pair of salivary glands is completed. Since these glands secrete silk they are called *silk glands.*

3. **Pupa.** The mature caterpiller stops feeding and excrete is last excreta and begin to secrete the stick-secretion from the silk glands through a very fine pore called *spinneret* situated on the hypopharynx. The secretion is continuous and after coming in contact with the air the sticky secretion is converted into a fine, long and solid thread of silk. The thread is made up of five filaments stuck together by *sericin* secreted by two other glands. The thread becomes wrapped around the body of larva forming a *cocoon.* This process continues for 3-4 days. The cocoon serves as comfortable house for the protection of the caterpillar for further development.

The cocoon is a thick, white or yellow and oval capsule. The outer or initial filaments of the cocoon are irregular, but the inner one that form the actual bed of the pupa is one long continuopus thread about 300-450 metres long wound in ring. The silk thread is secreted at the rate of 150 mm per minute. Within 15 days the caterpillar is transformed into a brownish *pupa* or *chrysalis.* The pupa lies dormant but undergoes metamorphosis. The larval organs such as prolegs, claspers, anal horn and mouth parts are lost. The adult organs develop. Within 12-15 days the adult is formed.

4. **Adult (Imago).** The adult secrets an alkaline fluid that moistens and softens one end of cocoon. The cocoon breaks at this end and the adult comes out. Soon after the emergence, the silk moths mate, lay eggs and die.

Economic Importance

The silkmoth is a very valuable insect as it gives us silk. Besides silk it gives *gut.*

SERICULTURE

Sericulture is the production of silk by rearing silkworms. The silk industry originated in China about 3000 B.C. A Chinese Princesses *Siling Shi* was the first to discover the art of reeling an unbroken filament from a cocoon. This art was kept a close secret for nearly 3000 years. This art later on spread to the rest of the world.

Sericulture is a regular industry. India has silk-producing centres in Assam, Bengal, Madras, Mysore, Punjab and Kashmir. Healthy eggs of high-yielding strains are procured from sericulture research stations. The eggs are placed in paper-lined trays made of spilt bamboo. The trays are kept out of the reach of ants. The eggs are periodically stirred by a feather. Larvae are given chopped leaves of a good quality mulberry trees 5 to 9 times a day. The pupae are not allowed to become adults, as the latter rupture the cocoon to escape, and thereby cut the silk thread of cocoon into pieces. About 10 days after cocoon formation, the pupae enclosed in them are killed by soaking the cocoons in hot water, by steaming them, by giving them dry heat in an oven or in the sun, or by fumigation. Some cocoons are kept safe. Their pupae are allowed to develop into adults to get seeds (eggs) for the next crop (brood).

Reeling of raw silk from cocoon

Reeling constitute an important aspect of sericulture because cocoon production is directly related to reeling industries. Before reeling the thread the cocoons, with dead pupae, are dipped in a container of hot water for more thn 10 minutes. During this period they are continuously stirred with a rod. For tasar silk special cooking techniques is employed. The cocoons are dipped in 0.5% Na_2CO_3 solution for 18 hours. Than cocoons are subjected to steam cooking for $2\frac{1}{2}$ hours. After 24 hour the cocoons are treated with 0.5% Na_2CO_3 solution for 15 minutes. Due to this process, their outer portion is loosened and removed in the form of long tapes and the end of the continuous filament is found. The filaments of several cocoon are picked up and passed through the 'glass eye' on to the reel. The thread thus reeled foms the *raw silk* of commerce. About one kilogram of raw silk is obtained from nearly 55,000 cocoons and one cocoon yields about 300 metres of silk-thread. The waste superficial threads and damaged cocoons are combed and teased. The resulting fibres are spun and this is spun silk.

Mulberry-silk is restricted to Purnea district, along the border of West Bengal. The total production of silk is of the value of about 3.5 crores in Bihar. Munga silk is only produced in Assam.

56

MOUTH PARTS IN INSECTS

Every organism should possess, in the view of feeding, organs which are either primaries or secondaries modified structures those enable the animals to feed and live as long as they are alive. The insects shows various specializations in their mouth parts. No doubt the insects are most successful forms among invertebrates and are adapted to the nature or environment so intimately as that their number is increasing constantly. The success of this group in all respective reveals vivid variations in mouth parts that are also being modified according with their modes of lives.

According to the food and manner of feeding the mouth parts are of following types:

1. Biting and chewing type

2. Chewing and lapping type

3. Rasping and sucking type

4. Piercing and sucking type

5. Sponging type

6. Siphoning type

Out of these the rasping and sucking type is considered to be less important because the parts radiating to the piercing and sucking type.

I. Biting and chewing type

The biting and chewing type mouth parts are considered to be most primitive and they are said to be mandibulate types of mouth parts. These mouth parts are found in groups such as Orthoptera, Isoptera, some Coleperans etc. The mechanism of feeding is simple because that are meant for pinch off, chewing up and swallowing the pieces of plant or animal tissue.

The mouth parts consists of :

(i) Paired mandibles

(ii) Paired maxillae

(iii) Labium or lower lip.

(iv) Labrum or upper lip

(v) Hypopharynx

(vi) Epipharynx

These mouth parts are further divided into three subdivisions:

(a) Grinding type

(b) Grasping or Predaceous type

(c) Mandible-suctorial type.

(a) ***Grinding type.*** Especially this type is found among cockroaches and grasshoppers. Because of being considered them as generalized one so we have to describe the various parts of mouth parts first:

(i) *Labrum or upper lip.* It forms the a roof of the mouth cavity, hanging from clypeus and variable in shape and size.

(ii) *Maxillae.* These are paired and attached laterally. Each maxilla consists of a basal part, the protopodite which is made up of two segments, *cardo* and *stipes.* The stipe bears two branches distales, the inner *endopodite* and an outer *exopodite.* The endopodite consists of two lobes, inner *lacina* and outer *galea* which bears the taste buds. The exopodite is a branch of stipes possessing 5-jointed *maxillary palp* which acts as tectile organ.

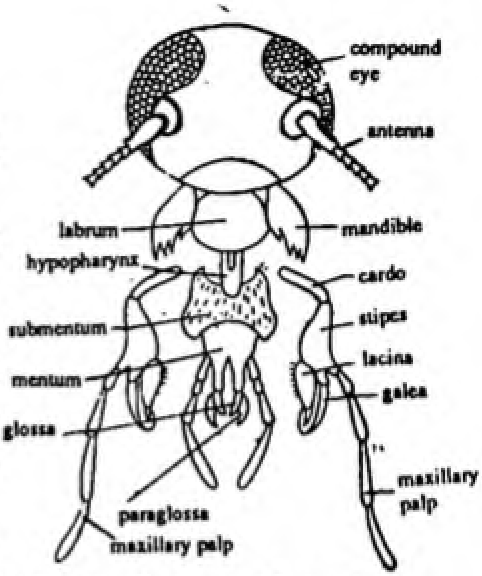


Fig. 56.1 Mouth parts of *Cockroach.*

(iii) *Mandibles.* A pair of mandibles lie in the mouth cavity and they work transversely to masticate or grind the food. Each one is an unjointed and triangular piece usually, which are very stout. The inner edge of mandible bears tooth-like denticles which interlock while capturing the prey. The smooth molar area provides the masticatory surface. Proximal to molar area is a membranous lobe, the *prostheca* which bears sensory hairs.

(iv) *Labium or lower lip.* It forms the floor of mouth cavity. It is formed by the fusion of two maxilla-like appendages. The basal large part is *submentum,* which supports the some-what smaller *mentum.* The mentum supports the *prementum* and paired *glossae* and *paraglossae* together constitute the *ligula.* The prementum bears, on each side, a three-jointed *labial palp* borne on a basal projection, the *palpiger.*

(v) *Hypopharynx.* It is a median process called the tongue, occupying in the buccal cavity. It bears at the base an opening of salivary duct.

(vi) *Epipharynx.* It is a membrane like structure lining the under surface of the labrum and bears taste buds.

(b) ***Grasping or predaceous type.*** This category is found in Isoptera especially in the soldier casts which are provided with strong mandibles.

(c) ***Mandible-suctorial type.*** It is common in ants. Their mandibles are sickle-shaped possessing a groove ventrally and are provided with sucking tube in order to suck up the juice of the prey. The maxillae are slender and fits into the groove of mandible of its side.

2. Chewing and lapping type

This type of mouth parts are seen in the group Hymenoptera such as bees and wasps. Here the mouth parts are modified for collecting the nectar and pollen of the flowers and moulding the wax and serve for both chewing and licking of the food. The mouth parts are the same in all respect as that found in generalized type except in a few modifications. The epipharynx projects below the labrum and the mandibles are soft or smooth and spatulate. In workers these are utilized in building the honey combs. Galea is elongated and blade-like but the maxillary palps are vestigial. The labium is articulated with basal triangular postmentum or submentum and mantum which is having muscles. Paraglossae are greatly reduced where as the glossae are much elongated, constituting the retractile ligular tongue which terminated distally as a

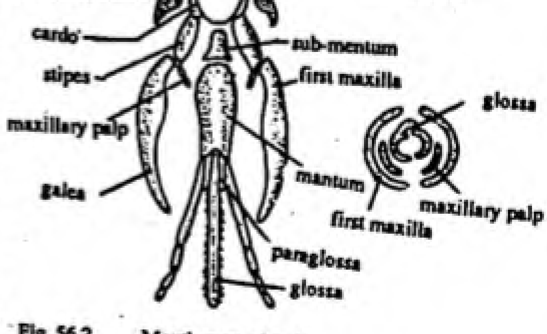


Fig. 56.2 Mouth parts of *Apis.*

honeyspoon or labellium. The labial palps are well developed when the animal wished to take food, the terminal lobes or maxillary galeae and labial palps are brought close together to form a groove or hollow tube which can be inserted into the flower where the labellum moves forwards and backwards to collect pollen and to suck up the nectar of flower. There are two views either the liquid food can be drawn by automatic capillary action or it is the action of pharyngeal muscles.

3. Rasping and sucking type

Such type of mouth parts are seen in Thrips. The mouth parts are adapted for lacerating and sucking. One of the mandible is reduced markedly but there is nothing like piercing. The stylet is used for escaping the surface of the prey.

4. Piercing and sucking type

This type of mouthparts are common in bugs, mosquitoes, aphids, scale insects, flea and some other forms in which the mouth parts are modified with regards to diet. These are modified in four subtypes:

(a) *Hemipterious type.* Here the four needle-like stylets, which are grooved lengthwise and lying in the long jointed lower-lip rostrum, are present. The labium is modified into 3 jointed rostrum. A pair of sharp, pointed mandibles and a pair of slightly shorter maxillae with serrated edges are present. These four are modified into stylets and are rectactile and protractile, unlike that those of a mosquito. The labial and maxillary palps are altogether absent. The inner maxillary surface are grooved so as to form two exceedingly fine channels out of which one is feeding canal and the other is salivary canal. The labrum does not take part into the formation of food channel.

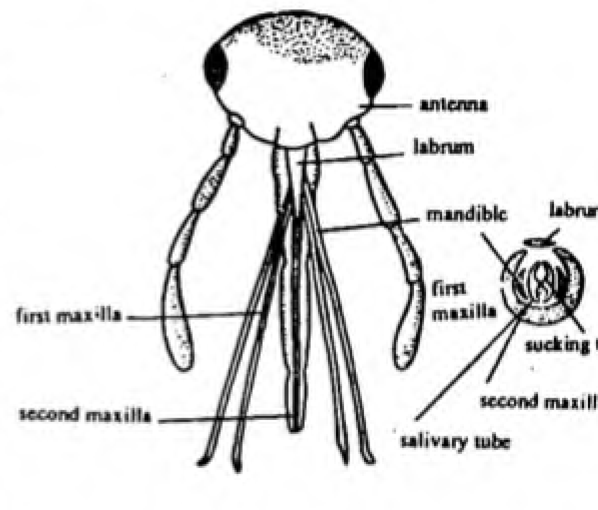


Fig. 56.3 Mouth parts of *Cimex*.

The mechanism of feeding is that the beak is bent and piercing organs are stylets which are gliding up and down finally sunk deeply into the flesh of the victim. By the strong motion of the pharynx the blood or juice is sucked up through the tube formed of piercing organs. It is found in bedbugs and in some aquatic bugs (*Sphaerodoma*).

(b) *Anoplurous type.* Such sub-type of mouth parts are found in hair-louse in which the mouthparts are withdrawn into a pouch under the pharynx, if not in use. The pouch is said to be style sac, the rest is all the same as we found in bugs. Besides a minute tooth- like structure on the head called buccal denticle is present. The latter enable the louse to anchor its head to the skin of the host thereby it starts feeding.

(c) *Flea type.* This sub-type of mouth parts are well marked in fleas. Which are parasites on the domesticated animals like dogs, rats etc. This type is characterized by the presence of a pair of long blade-like mandibles with serrated edges. Labium consisting of two halves fused at their bases so as to form a hollow proboscis enclosing the mandibles, the labrum and the epipharynx, which are fused to cover up the mid-dorsal opening of the labium. These mouth parts are adapted to pierce and suck to the blood of the host.

(d) *Dipterous type.* This sub-type is found in mosquitoes. These are adopted for piercing and sucking. The mandibles and maxillae are modified into fine rod-like stylets which are used to pierce the skin of host. The labrum is long needle-like and fused with the epitharynx and covers the mid-dorsal opening of the labium. The hypo-pharynx is double edged, served with a mid-dorsal groove, which forms the salivary passage for the secretion of salivary glands. The labial palps are absent, but maxillary palps are present.

While feeding, the hypopharynx and labrum-epipharynx become closely applied to enclose a tubular passage for the ascend of the blood through this tube. The salivary secretion is poured through the groove of hypopharynx in order to check the clotting of blood

In male mosquitoes, the mandibles are totally absent so that they suck plant juice, whereas the female sucks the blood of

human beings and other cattles because of piercing the skin by powerful mandibles.

5. Sponging type

This type of mouth parts are found in Diptera such as house-flies, *calliphora* and others. The adaptability of the mouth parts suited alone to suck as the liquid and not piercing the tissue of enemy. These forms are capable of sucking even solid food which has to be converted into liquid by their saliva before sucking.

The labium is modified into so called *proboscis* which has got a groove with membranous sides and the groove is covered by labrum, epipharynx and hypopharynx dorsally. The proboscis expands dorsally into a oral-disc or labellum which possesses a number of pseudotracheae. Its proximal part is cone-like known as rostrum bearing maxillary palp and the middle is haustellum with a mid-dorsal groove serving as a food passage. All the pseudotracheae are converging into the central aperture, the *mouth*, which leads into the food passage. The mandibles are absent while the maxillae are represented by two maxillary palps, each made up of a single piece.

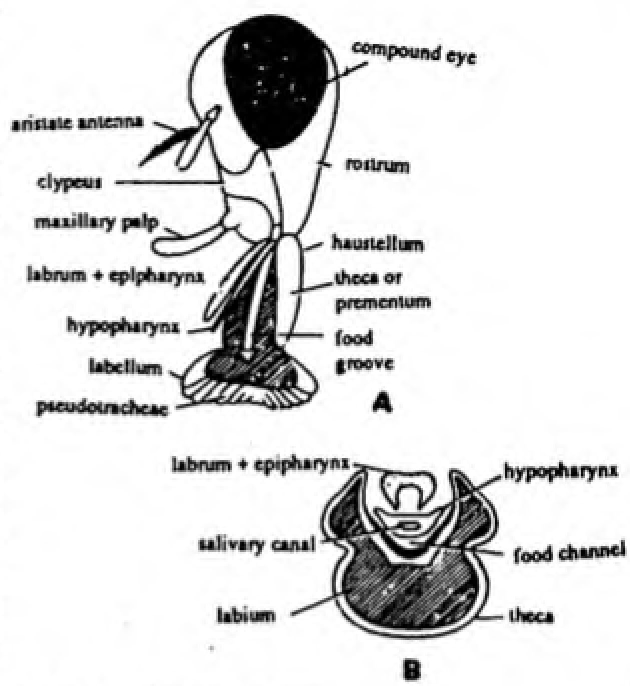


Fig. 56.4 Mouthparts of *musca*.

Generally the two labellae are kept retracted upwards and backwards during rest, but these labellae are protracted and expanded and placed over the liquid food. The fly can consumes a solid food particle of an easily soluble kind like sugar, the fly, extrude a drop of saliva to make the solid in dissolved form. The liquid food is drawn by the pseudotracheae and than passed on to the food-canal which is formed by labrum-epitharynx and hypopharynx lying in the mid-dorsal groove of the haustellum.

6. Siphoning type

This type of mouth parts are seen in lepidopterans (butterflies and moths). These are highly specialized for sucking up the juice of flowers and fruits.

The mandibles are usually absent but if present they are very much reduced. The labium is too much reduced. The maxillary palps are considerably vestigial. The labium is represented by a triangular plate bearing the labial palps. The galeae of maxillae are modified into a proboscis through which liquid is drawn up. The proboscis is kept coiled when it is in rest.

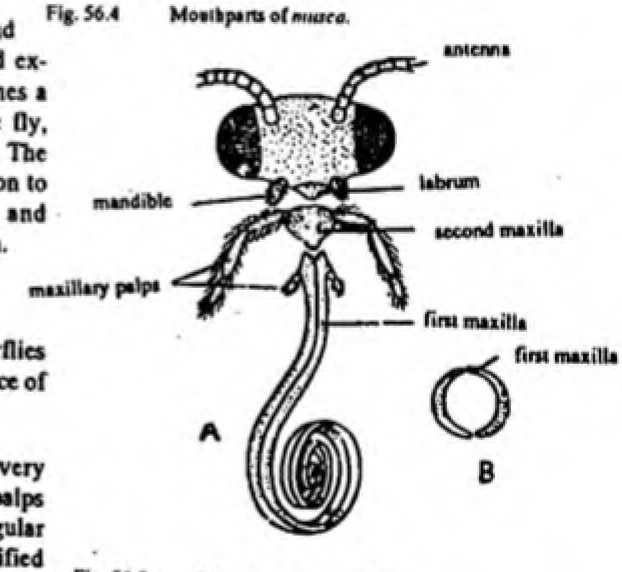


Fig. 56.5 Mouth parts of *Butterfly*.

When the insect wants to feed than only the watch spring-like proboscis becomes uncoiled and extended to reach the spot where its diet is available.

In Hexapoda the function of the mouth elements is seen in two quite different lines upon which the insects are grouped as the mandibulate possessing the biting and chewing type and other in Haustellata consisting of sucking. From the evolutionary point of view it is decided that the biting and chewing parts are generalized primitive kind from which other types have given rise.

57

RESPIRATION IN INSECTS

The respiration includes both physical and chemical processes. The physical envolves the transportation of oxygen to the tissue and removal of carbon dioxide from tissue where as chemical process envolves the oxidation of carbohydrates with the formation of energy, carbon dioxide and water. In the case of vertebrates the oxygen is transported to the tissue by blood with the help of a respiratory pigment, the *haemoglobin*, but in the case of insects the blood plays very little role in transportation of oxygen to the tissue except the larvae of *Chironomus* which have haemoglobin in blood plasma.

Various types of respiratory organs are present among the insects according to their mode of lives.

I. Tracheal Respiration in terrestrial insects

In the insects, particularly in terrestrial mode of life, the respiratory organs are tracheal tubes. The tracheal tubes are invagination of the ectoderm and are internally lined by cuticular intima which is thickened by spiral filaments called *taenidia*. It not only gives the support to tracheal branches but also prevents the collapse of wall. These tracheal trunks divide and redivide and ultimately ends into a culster of tubes called *tracheoles*. The tracheole devoid of taenidia. The tracheoles are lines by a protein called *trachein*. The ultimate trachioles enter the individual cells of the body, and are partly filled with a fluid called tracheole fluid at their distal end. By the reduction in the amount of fluid, more of the surface walls of the tubules in exposed to oxygen and more oxygen is immediately supplied to the tissues.

In certain insects like cicadas, honey bees, butterflies etc. the tracheae dilate into air sacs of different sizes. The air sacs lack the spiral thickening, allow an increased supply of oxygen and afford a greater breathing capacity of the insect.

The tracheal branches open to outside by many apertures called *spiracles*. The spiracles are elongated or circular apertures and situated on the lateral sides of the body. Usually these are 10 pairs in number, 2 pairs are thoracic and 8 pairs abdominal. Each spiracle is supported by a small annular sclerite called *peritreme*. The spiracles can be closed or opened by spiracular muscles. In some cases the spiracles are absent so that on the basis of presence or absence of spiracles the system is divided into open type or closed type.

In the open type of tracheal system when all the spiracles remain open it is called *holopneustic*, as found in most of the adults and some larvae. When one or more pairs of spiracles remain closed the system is called *hemipneustic*. It is seen in some flies, butterflies, beetles etc., when the posterior spiracles are functional, the system is called *metapneustic*. When the functional spiracles are present only on prothorax, it is called *propeneustic* when the spiracles are absent it is called *apneustic*.

II. Close type of respiration in aquatic insects.

The close type is present in some aquatic insects and endoparasitic larvae. Insects living in aquatic medium have different adaptations. Insects of order Odonata, Placoptera and Ephemeroptera áre primarily aquatic where as insects of order Hemiptera, Coleoptera, Lepidoptera, Diptera and Neuroptera are secondarily aquatic. Most of the forms are aquatic only during larval stages.

The inmature stages of Odoneta, Plecoptera and Ephemeroptera are aquatic and draw oxygen through general body surface or specialised structures, the gills, so that they have two types of respiration:

1. Skin or cutaneous respiration.

2. Gill respiration.

1. ***Cutaneous respiration.*** In those, insects where cutaneous respiration occurs, the tracheal system is fairly developed without spiracles. The gaseous exchanges takes place through general body surface by diffusion. The larvae of aquatic lepidopterans show this type of respiration.

2. ***Gill respiration.*** It provides an enlarged respiratory surface formed by evagination of integument. The gills are usually thin walled. In aquatic forms three types of gills are present:

   (i) Tracheal gills

   (ii) Spiracular gills

   (iii) Blood or anal gills.

(i) *Tracheal gills.* It is formed by hallow evagination of integument or intestinal wall. These are supplied by fine tracheal branches and known as tracheal gills. The tracheal gills may be filamentous (as present in the case of Plecoptera, some Ephemeroptera and Trichoptera) or plate-like (as in larval Odoneta and some Ephemeroptera). In some odonates peculiar rectal gills are present. These are six folds formed by the rectal wall. They are well supplied with tracheal branches and hence sometimes they are referred as branchial basket. The insect draws water in the rectum through the anus and exchange of gases takes place here.

(ii) *Spiracular gills.* These gills are found in some coleopteran and dipteran aquatic pupae. Here 1 or 2 pairs of spiracles are drawn out to long processes which have named as spiracular gills by *Hinton* (1953). Some of the pupae can live in damp climate. So that the gills are considered to adopted both for aeral as well as aquatic respiration through gill surface.

(iii) *Blood or anal gills.* They are thin diverticulae of integument or of the proctodaeum. They are present in aquatic larvae of beetle (*Hydrobia*). These gills are supplies with blood hence they are known as blood gills but in the case of larvae of *Tipulid* the tracheal branches are also present so that they function as the tracheal gills as well as blood gills. In the case of blood gills the respiratory function has not been demonstrated. *Wigglesworth* (1953) have shown in mosquitoes larvae the blood gills are concerned with the regulation of movement of ions absorbed from the water.

III. Open type of respiration in aquatic insects

This type of system is found in secondary aquatic forms belonging to order Hemiptera and Coleoptera. They have spiracles through which tracheal branches draw in atmospheric air. Since the insects live in water they have developed certain adaptations to ensure the supply of air while they are in submerged stage. The various modifications are:

1. *Air stores.* Some of the nymphs and adults of water-boatman and the back-swimmers and also the nymphs of *Spherodema*, certain amount of air is carries by the insect attached to some part of body when the insect dips in water. In the case of water boatman and back swimmer air is carried on ventral surface of body. The air is kept by hairs called *hydrofuge hairs*, which resist penetration of the air filled by water. In adults of some beetles the air is carries by wing cover or elytra. The spiracles remain in contact with air and draws it but the air is not available for a long time so that the insect have to come again and again to take fresh air bubbles to the surface. Besides in respiration the air bubbles also has hydrostatic function.

2. *Gaseous plastron.* This plastron is a permanent bubble held by various means around the body by certain insects. The plastron communicate with spiracles so that the spiracles are able to draw air from water. So that it has permanent nature. The insect has not to come on surface again and again for fresh air. *Torpe* (1950) described such type of respiration in certain aquatic insects.

3. *Air tubes.* Many insects which remains submerged in water acquire and obtain air through one or two tubes which can break the water surface. In such insects the spiracles are situated at the tip of the tube and the rest of spiracles are non-functional and hence either may closed or under-developed (larvae of mosquitoes). In the *Culex* larvae a tube projects above the surface of water to draw air in. The rat-tiled (dipteran larvae) have the tube of about 3-4 inches long. When the larva remains submerged in water the long tube projects outside to draw atmospheric air. While this type of tube present in different form in some aquatic Hemiptera such as *Nepa*, *Belostoma* and *Spherodema*, there is a long respiratory spihon through which air is drawn.

4. *Plant perforating spiracles.* In some insects the spiracles are situated on sharp-pointed processes which are penetrated by insect into the air cavities of hydrophytes for the purpose of getting air. This is found in the larvae and pupae of certain colepterans

and dipterans.

Thus from the above account, it is clear that aquatic insects have assumed several modifications in the respiratory system to enable them to live in water. Without such modifications it would not have possible to them to lead an equatic life.

58

METAMORPHOSIS IN INSECTS

Insects develop from the primordial cells in the ovaries of females. The eggs are laid and hatched out side the body after a variable time. The development within the egg is called embryonic development and period after hatching of egg is called post-embryonic development. One of the most characteristic features of insects is the fact that they almost always hatch in a condition morphologically different from that of the imago. In order to reach the latter instar they consequently have to pass through changes of form which are collectively termed *metamorrphosis*, these are usually most pronounced towards the end postembryonic development and they are accompanied by physiological and biochemical changes. During metamorphosis the exoskeleton or outer skin is cast off periodically. This process is known as *moulting* or *ecdysis*. The larval stage between two moultings is called *stadium*. Thus the insect growes by a series of changes and these growing stages are called *instars*. The number of moults vary but is constant for a given species. On the basis of these changes the metamosphosis is distinguished into following types:

1. Ametabolous development or no metamorphosis
2. Hemimetabolous development or incomplete metamorphosis
3. Paurometabolous development or gradual metamorphosis
4. Holometabolous development or complete matamorphosis
5. Hypermetabolous development

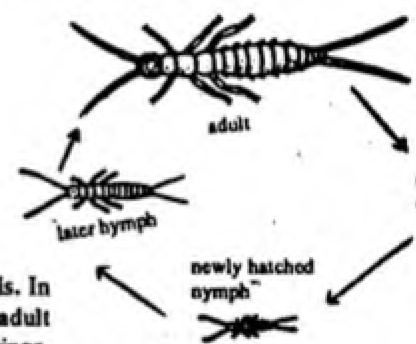


Fig. 58.1 *Lepisma*.

1. Ametabolus development or development with no metamorphosis. In some primitive forms of insects the egg hatches in a form that resembles the adult in all morphological details except in size and colour and in the absence of wings, reproductive organs and external genitalia (styles etc.). The stages of development are: egg-young-adult. Ametabolus development is seen in *Lepisma*, spring tails (Thysanura, Collembola and Protura i.e. in apterous insects).

2. Hemimetabolous development or development with incomplete metamorphosis. This type of life-cycle includes gradual metamorphosis as in paurometabolous type except that the eggs are laid in water and develop in aquatic nymphs or naiads. These naiads posses tracheal gills but adults are formed from naiads by repeated moults and maturity. Final moult results in the winged adult. The developmental stages are: egg-naiad-adult. Hemimetabolous development is seen in Mayflies, Dragonflies, Stone flies etc.

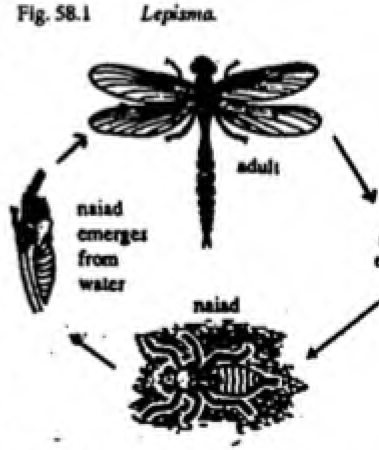


Fig. 58.2 *Hemimetabolous* development.

3. Paurometabolous development or development with gradual metamorphosis. In case of gradual metamorphosis, the newly hatched creature resembles an adult in general body form, but lacks wings and external genital appendages. The young or the nymph undergoes several nymphal stages through successive moultings to become an adult. The developmental stages are: egg-nymph-adult. Paurometabolous development occurs in grasshopper, cockroaches etc.

4. Holometabolous development or development with complete metamorphosis. In complete metamorphosis the development includes four developmental stages - egg-larava-pupa, adult. The larva that hatches out of the egg is totally different

from the adult both in structure as well as in habit. The larvae are classified into following types:

(i) ***Protopod larvae.*** This type is found in the primary larvae of certain parasitic Hymenoptera. The eggs of such species contain little yolk and the larvae emerge are an early embryonic phase. The nervous and respiratory systems are undeveloped.

(ii) ***Polypod larvae.*** Typical examples of this type are the so called eruciform larvae of most of the Lepidoptera, sawflies and scorpion flies. They bear well defined segmentation, presence of abdominal limbs or prolegs and a peripneustic tracheal system. Antennae and thoracic legs are small, compound eyes, ocelli and wing pads are totally absent.

(iii) ***Oligopod larvae.*** These are characterized by the presence of more or less well-developed thoracic legs and absence of abdominal appendages except sometimes for a pair of similar caudal process. Two common types can be distinguished.

(a) *Campodeiform larva.* They are so called from their resemblance to *Campodea* (Thysanuran insect). It bears an elongated more or less fusiform somewhat depressed body which is often well sclerotized and markedly prognathous head, long thoracic legs and usually a pair of terminal abdominal process. Compound eyes, dorsal ocelli and wing pads are absent. Campodeiform larvae occur in the Neuroptera, some Coleptera, Trichoptera and Strepsiptera.

(b) *Scarabeaeiform larva.* These are subcylindrical, C-shaped larvae with shorter thoracic legs, a soft fleshy body and no caudal process. The larvae are seen in Scarabaeoidea, in Coleopteran families etc.

(iv) ***Apodous larvae.*** In this type the trunk appendages are completely absent and most cases are probably derived from oligopod type.

Such a larvae are seen is several families of Coleoptera.

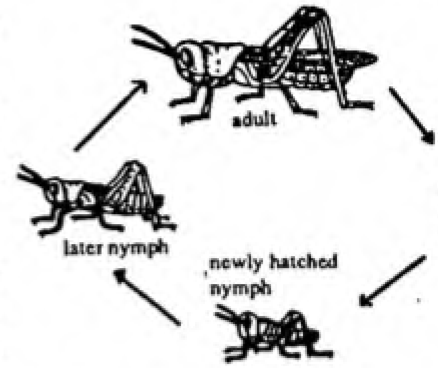


Fig. 58.3 *Paurometa* bolous development.

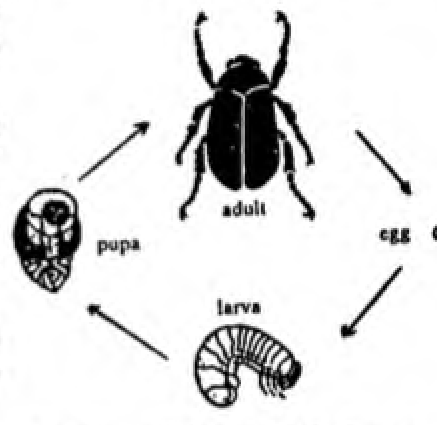


Fig. 58.4 *Holometabolous* development.

After several changes the larva turns into pupa. The pupa appears to be inactive externally but internally it is very active and forms the imago. The following types of pupae are distinguished by *Hinton* (1946):

(a) *Decticous pupae.* These have relatively powerful, sclerotized, articulated mandibles. This is the primitive type of pupa and is always of exarate i.e. the appendage, are not closely applied to the body but are used in locomotion. This type of pupa occurs in Neuroptera, Macoptera, most Trichoptera, in some lapidopteran families etc.

(b) *Adecticous pupae.* This type have a non-articulate mandibles and are not used in escaping from the cocoon. Three forms of adecticous pupae are recognizable.

(i) ***Exarate or decticous pupae.*** The appendages are free of any secondary attachment to the body. They are found in the Siphonoptera and Strepsiptera, most Coleoptera and Hymenoptera.

(ii) ***Obtect adecticous pupae.*** Here the appendages are firmly pressed against its body and are soldered down to it by a secretion produced at the last larval moult. These pupae occur in all higher Lepidoptera, some Coleoptera etc.

(iii) ***Coarctate pupae.*** This is an adecticous as well as exarate type of pupa which is enclosed in puparium. The puparium is formed from preceeding larval cuticle. It does not show any changes in external appearence. It is seen in Cyclorrhaphan Diptera.

5. Hypermetabolous development or development with hypermetamorphosis. When a developing insect passes through two or more markedly different larval instars it is said to undergo hypermetamorphosis. The last or final larval instar changes into non feeding, inactive stage called prepupa. It is enclosed in the cuticle of preceeding larval stage. Such a metamorphosis occurs in some Neuroptra, Coccidals and many endoparasitic Hymenoptera.

INTERNAL METAMORPHOSIS

In those cases where the metamorphosis is gradual or incomplete, the internal organs do not undergo any major modifications but some very minor changes are observed. In the case of holometabolous and hypermetabolous development major changes take place in internal organs because of different mode of life. All these modifications of internal organs takes place within the pupa. There may be other structural or physiological internal changes, so that the pupa is inactive externally but it is active internally. During early pupal stages internal organs break down or dissolved (probably as a result of lysosomal breakdown) or by phagocytes. This process is known as histolysis. This phenomenon differs in different insects. In some cases it is minor or may be major. After histolysis new tissues are formed from certain pad- like structures known as immaginal pads or histoblasts. This process is known as histogenesis. It is ultimately followed by a process of organogenesis. The internal changes within the pupa differ in different groups of insects. In Coleoptera, Lepidoptera, Hymenoptera and some Diptera intestine and other larval parts are greatly modified without general histolysis. Similarly in certain dipterans the general histolysis is noted so that all the organs are dissolved and reformed except the nervous system, heart, reproductive organs and thoracic appendages. The study of internal metamorphosis is not thoroughly studied in all the groups of insects but still it is unknown in some of the other groups of insects.

HORMONES AND THEIR ROLE IN METAMORPHOSIS

Insects have a rigid exoskeleton, because the exoskelton do not expand to allow for enlargement, insect growth is associated with the periodic shedding of the exoskeleton in a process known as ecdysis. Ecdysis is followed by the expansion and hardening of a new, soft, larger exoskeleton that has developed underneath the old exoskeleton. Thus, insect development includes a series of ecdysis or moults, and the stages between the moults, are known as instars.

In insect development, metamorphosis is the change in body form that converts an immature individual into an adult. Metamorphosis is either incomplete or complete comprising eggs-nymphs and adults in former case and eggs - larvae - pupae - adults in latter case. Several hormones regulate in insect growth, moulting and metamorphosis. The neurosecretory cells of the brain produce a brain hormone that travels along axons to a structure called corpus cadiacum, which is attached to the brain. From the corpus cardiacum, the brain hormone is released and carried to the prothoracic glands, which is stimulated to release ecdysone. Ecdysone is also called the moulting hormone or moult and maturation hormone because it promotes moulting and tend to spur the developmental process along toward pupation and adult-hood. During larval stage, the effect of ecdysone is countered by the action of juvenile hormone, secreted by corpus allatum. When juvenile hormone is secreted, the organism remains immature. In the last larval stage, however, juvenile hormone secretion decreases dramatically and the animal pupates and begins its transformation to the adult form.

From an evolutionary point of view, it is interesting that some plants produce compounds similar or identical to ecdysone or juvenile hormones. This apparently protects the plants by disrupting the development of insects that eat them.

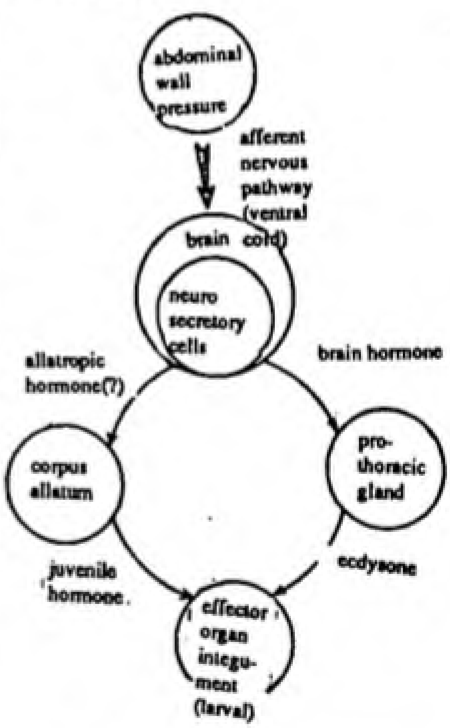


Fig. 58.5 Control of moult and metamorphosis in *insects*.

59

SCORPIONS

The scorpions are the oldest known terrestrial arthropods and they have been the first members of this phylum to have conquered land. The scorpions are most common in tropical and subtropical areas except New Zealand and oceanic islands. They are most abundent in the Gulf states and Southwest. About 800 species have been described some common genera are *Palamnaeus*, *Buthus* etc.

SYSTEMATIC POSITION

Phylum	-	Arthropoda
Class	-	Arachnida
Order	-	Scorpionda
Type	-	*Scorpion*

HABITS AND HABITAT

Scorpions are generally secretive and nocturnal, hiding by day under stones and wood and in burrows in the grounds. But there are species associated with vegetation. They are often found near dwellings. Scorpions are popularly believed to inhibit desert regions, but although many desert species exist, they are by no means restricted to arid regions. Many scorpion species require a humid environment and live in tropical rain forests and similar jungle habitats. They are carnivorous and feed on small arthropods, especially spiders and nocturnal insects, cannibalism is also practised. These are solitary animals and never live in groups. all the scorpions are viviparous and the females carry the young ones on their backs for some times, about a week.

EXTERNAL FEATURES

Shape and Size. The body is long, narrow and dorso-ventrally flatenned. The size varies from 3 to 8 cm. in length. The smallest species is the Middle Eastern *Microbuthus pusillus* which is about 13 mm. long. The largest one is African Pandinus *imperator* which measures about 18 cm. in length. The largest Indian species, *Palamnaeus swwammerdami*, grows to a length of about 15 cm. while *Buthus tamulus*, a common species, reaches a length of nearly 8 cm.

Colouration. The colour is variable, usually corresponding with the habitat of the animal which is generally blackish dorsally and slightly light coloured ventrally. The species, which are living in tropical jungles, are of shining black colour, and the species which are found in the sand are pale-yellow in colour usually the dorsal surface is much darker in colour than those of the ventral surface.

Division of body. The scorpion body consists of a prosoma or cephalothorax covered by a single carapace and a long abdomen or opisthosoma.

(i) Prosoma. It is the broad flat, anterior region composed of the head and thorax which are fused together. It is formed by the fusion of a preoral and six post-oral segments but only six are distinguished in the adult. The segments are marked by the presence of six pairs of appendages on the ventral side. Dorsally, the prosoma is covered by a large, shield like exoskeletal plate, somewhat squarish in form. It is known as *carapace*. Its anterior margin is divided into right and left frontal lobes by a median notch. Two to five pairs of lateral eyes and a pair of median eyes can be distinguished along the antero-lateral margin and in the middle of the *carapace*. These are simple eyes. On the ventral surface there is a narrow triangular plate, the ***sternum***, situated

medially between the coxae of 3rd and 4th pairs of legs.

A small mouth is situated on the anterior end of the prosoma towards the ventral side between the cephalic appendages.

(ii) Opisthosoma. The prosoma is followed by a long opisthosoma. It is divisible into two parts: anterior mesosoma or preabdomen and posterior metasoma or post abdomen.

(a) *Mesosoma.* It consists of seven segments in the adult. Each segment of the mesosoma is covered by two firm chitinous sclerites tergum on dorsal side and sternum on ventral side. The tergum and sternum of each segment are laterally connected by pleural membranes which are soft and flexible. The sternum of the first segment is small and bears the median genital aperture which is covered by a plate-like, rounded, bifid and movable genital *operculum.* The sternum of second segment bears a pair of comb-like pectines. A pectine consists of 3 jointed stem or shaft or handle bearing a row of 4 to 36 slender processes along the posterior border. The pectines are tectile organs. The sterna of 3rd, 4th, 5th and 6th mesosomal segments bear a pair of lateral, oblique, slit-like apertures known as stigmata. Each stigmata leads into the pulmonary sac. The sternum of last segment does not bear any appendage.

(b) *Metasoma.* The slender metosoma or post-abdomen is often wrongly called a tail. It is held upraised, arching over the back in a moving scorpion. It consists of five cylindrical segments, each enclosed with in a complete chitinous ring. The last segment bears the anus on its post-ventral side and a stinging apparatus or telson. The telson consists of a swollen base, the *vesicle* or *ampulla*, and a curved and pointed spine, the *aculeus.* It remains attached to the last segment by means of a flexible membrane. Inside the vesicle lies a pair of poison glands, the ducts of which open by a pair of minute apertures at the tip of the spine.

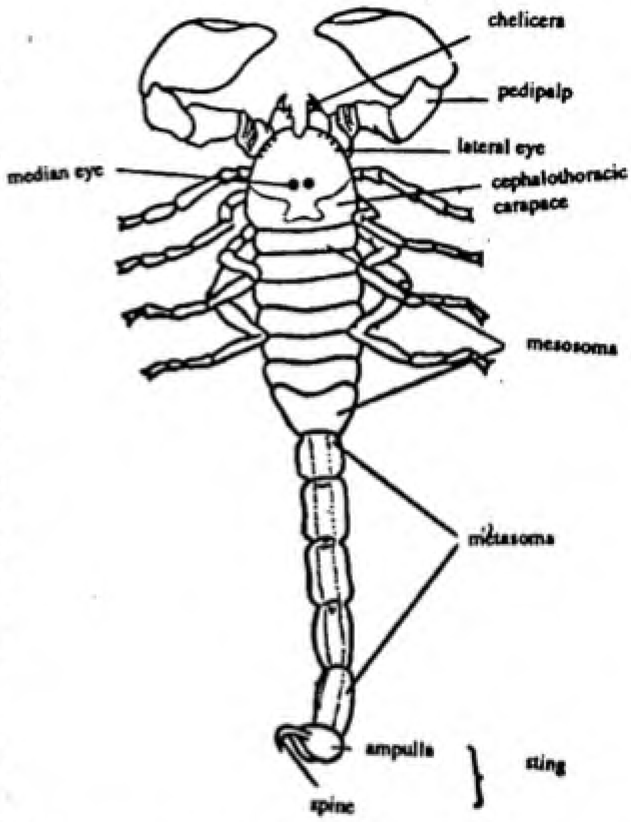


Fig. 59.1 *Scorpion.* Dorsal view.

The venom of most scorpions, although sufficiently toxic to kill many invetebrates, is not harmful to man. At most, the sting in equivalent to that of a hornet. However, certain species exist that possess a highly toxic venom that can be fatal to man. *Androctonus australis* of the Sahara Desert has venom equivalent in toxicity to cobra venom, and this venom can kill a dog in seven minutes. The neurotoxic venom of scorpions is very painful and may cause paralysis of respiratory muscles or cardiac failure in fatal cases.

APPENDAGES

The cephalothorax bears 6 pairs of appendages, these are a pair of chelicerae, a pair of pedipalpi and four pairs of walking legs. Of these the chelicerae are preoral and remaining appendages are postoral.

(i) *Chelicerae.* The chelicerae are short but stout appendages. They lie close together at the anterior end of the cephalothorax. Each consists of three podomeres. The basal podomere is ring-like and concealed beneath the carapace. The middle and distal podomeres together form a grasping apparatus called the chela or pincer for holding the prey during feeding. The middle podomere is large, bears setae and is produced on the inner side into a conical toothed process that forms the immovable

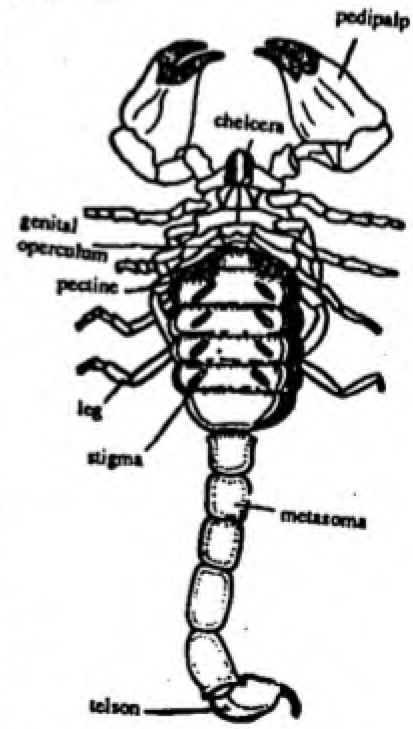


Fig. 59.2 *Scorpion.* Ventral view.

finger of the chela. The distal of interal segments is small, curved and toothed. It forms the movable finger of the chela.

(ii) *Pedipalpi.* Behind the chelicerae are a pair of powerful and clawed appendages called pedipalpi. Each pedipalp is made of six segments, *viz., coxa, trochanter, humerus, brachium, manus* and movable *finger.* The coxa is small and situated on the side of preoral cavity beneath the carapace. On each coxa there is a gnathobase towards the mouth. The gnathobases of both sides serve as jaws, protruding in the preoral cavity and help in squeezing and crushing the body of the prey.

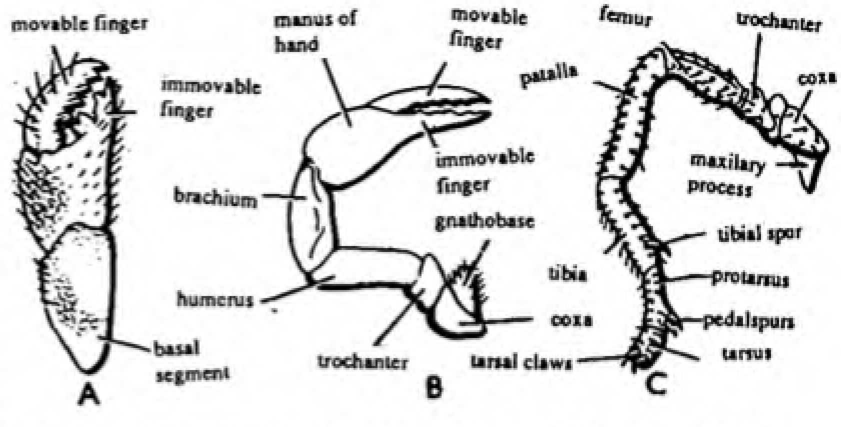


Fig. 59.3 *Scorpion* appendages. A—Chilicera, B—Pedipalp, C— First walking leg.

The trochanter follows coxa and is irregularly shaped having spinous anterior margin. At the right angle to longitudinal axis of trochanter, there is a stout and powerful humerus. The branchium lies above the numerus and is directed forward and is provide with granular crests. The manus is longest segment and it forms a powerful chela with the movable finger which is movably articulated and help in siezing the prey.

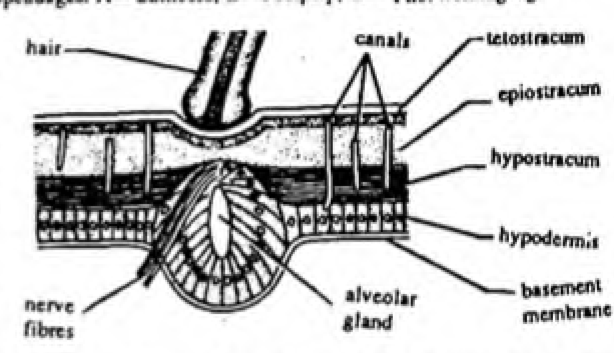


Fig. 59.4 *Scorpion.* T.S. of poison vesicles with two poison of gland and glandula plicata.

(iii) *Walking legs.* There are four pairs of walking legs, attached to the cephalothorax. All the legs are alike and are used for walking. Each leg consists of seven podomeres, *coxa, trochanter, femur, patella, tibia, prototarsus* and *tarsus.*

The coxae of 1st and 2nd pairs are provided with forwardly- directed triangular maxillary processes or gnathobases or endites. Coxae are very small, short, movable, except those of the fourth leg, which are longer. The coxae of the second pair meet with each other in the middle line while the coxae of the 3rd and 4th pairs are immovable and joined together but they do not meet in the middle line of the body and are separated by sternum of the cephalothorax. The trochanter is a short and stout segment, moving in all the directions. It is followed by a long, movable femur. The patella is an important podomere, which gives the leg a double knee, which moves down-wards on the end of the femur. Tibia is a part of the leg, which turns down abruptly on the patella. The tarsus is a long subterminal segment. In-between the tibia and tarsus is a structure, called tibial spur, while the tarsus bears a pedal spur. Pretarsus is provided on its lower side with hairs or spines or both. Each tarsus bears at its apex a pair of large claws, called superior claws and smaller inferior claws. Inferior claws are generally injured and their ends are removed.

BODY WALL

The body wall consists of three layers:

(i) Cuticle

(ii) Hypodermis

(iii) Basement membrane.

(i) **Cuticle.** The outermost layer is a brilliantly coloures non-living chitinous layer which is secreted by the hypodermis. The cuticle is made up of three layers. (a) a superficial cuticle, *telostracum* (b) the middle layer, *epiostracum* and (c) the lower lamellous layer, *hypostracum.* The cuticle is traversed by canals which open outside on the surface. In these openings are lodged the duct of secretory glands which are located in the hypodermis.

(ii) **Hypodermis.** It consists of a single layer of columnar cells filled with pigment granules.

(iii) **Basement membrane.** It is a thin and structureless layer. The hypodermal cells rest on this membrane.

Various kinds of projections are found on the cuticle:

(a) *Dermatidia.* These are small chitinous protuberences on the chela.

(b) *Coelodermatidia.* They occur in the form of hollow projections on the integument. They form hairs, spines, bristles, spur and claws etc. of tarsus.

(c) *Dermal glands.* These are known as alveolar glands occur in the chelae, pedipalpi and telson.

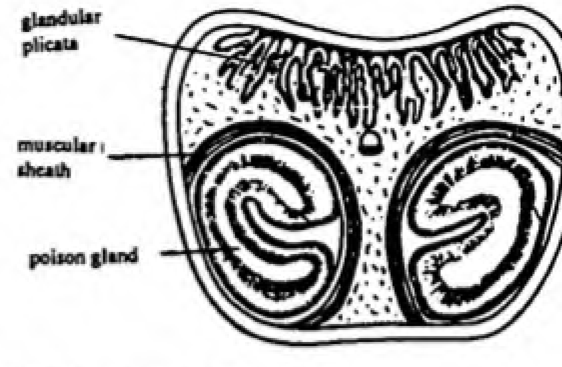


Fig. 59.5 *Scorpion.* Endosternite.

Glandula Plicata. The males of some species of genus *Bothriurus* are provided, on the dorsal surface of the poison vesicle, with a scutellithe hypodermis forms a special organ consisting of numerous longitudinal folds of cuboidal epithelium. These folds are longer in middle and lower at margins and are glandular. As they are found only in males they are supposed to play some role in sexual reproduction.

ENDOSKELETON

The endoskeleton of prosoma and mesosoma is present in the form of cartilaginous plate called *endosternite.* It is placed above the nerve cord and alimentary canal. It possesses apertures for the passage of the intestine and aorta. Its edges are produced into anterior, posterior and lateral processes for the attachment of muscles which control the movements of appendages. Another similar skeletal piece lies ventral to the nerve cord in the segment which bears pectines. The body of endosternite is unites posteriosly with a chitinous plate, called *diaphragm* which possesses apertures for the passage of nerve cord, intestine dorsal aorta and muscles.

Musculature. There is one pair of muscles lies in cephalothorax attached to it by one end and by other to the endosternite above nerve cord. In the pre-abdomen there are 8 pairs of dorso-ventral muscles on the left and right of midgut, running from the dorsal to the ventral surface of the body.

DIGESTIVE SYSTEM

The digestive system comprises the alimentary canal and digestive glands.

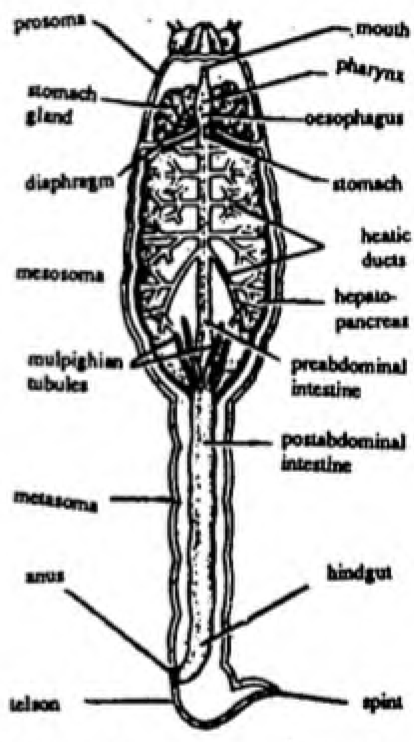


Fig. 59.6 *Scorpion.* Alimentary canal.

I. Alimentary Canal. The alimentary canal is complete and tube like nearly uniform. It is differentiated into four district regions.

1. Pre oral cavity

2. Stomodaeum

3. Mesenteron

4. Proctodaeum

1. *Preoral cavity.* It is formed infront of mouth. It is enclosed above by the rostrum, infront by the coxae of chelicerae, on the sides by the coxae of the pedipalpi and by the maxillary processes of first two pairs of walking legs. A laterally compressed cushion-like structure called rostrum protrudes into the preoral cavity from the posterior side. The rostrum is provides with a set of muscle which can roll it into a tube for sucking the fluid into the pharynx.

2. ***Stomodaeum or foregut.*** It includes mouth, phanynx and oesophagus and is lined internally by the cuticle.

(i) *Mouth.* It is a small narrow and transverse aperture just behind the preoral cavity. Only juices and pulps can enter the narrow mouth. Mouth leads into pharynx.

(ii) *Pharynx.* The pharynx is a large, pear-shaped and muscular structure situated obliquely below the mouth. Due to the presence of several bundles of muscles radiating outwards from pharyngeal wall to the wall of the cephalothorax, its walls are highly elastic and capable of great dilation. The muscles serve the pharynx to act as a sucking organ so that the liquid food is sucked in through the mouth. The pharynx is followed by oesophagus.

(iii) *Oesophagus.* It is a short, narrow tube that passes through the nerve ring. The oesophagus extends into the midgut to from the sleve valve which prevents regurgitation of food. It leads into stomach.

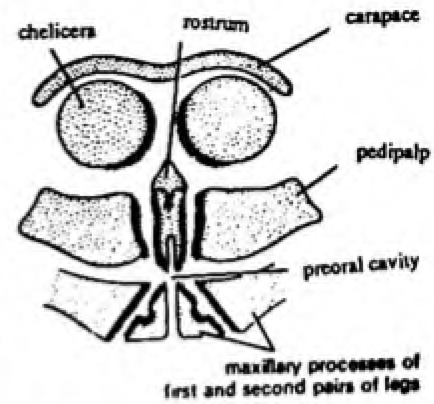


Fig. 59.7 *Scorpion.* T.S. through preoral cavity.

3. ***Mesentron or midgut.*** It includes stomach and intestine. These are lined with epithelium.

(i) *Stomach.* The stomach is a short thin walled and dilated tubular structure situated in the cephalothorax. It extends upto the diaphragm. A trilobed, brownish gland, lying in the cephalothorax opens into the stomach. *Huxley* regarded it as salivary gland but *Blanchard* and *Pavlovsky* called it stomach gland.

(ii) *Intestine.* It is the longest part of the alimentary canal and extends upto the last abdominal segment where it joins the hindgut. The intestine is wide tube-like structure with glandular wall. It is divisible into two parts: *Preadominal* and *postabdominal.* At the junction of these two is a constriction and from here one or two pairs of Malpighian tubules arise. These tubules are excretory in function.

4. ***Hindgut or proctodaeum.*** It is the smallest part of the alimentary canal, restricted to the last metasomatic segment, it is internally lined by chitin and opens to the exterior through the anal aperture situated ventrally at the base of the stinging apparatus.

II. Digestive glands. There are a pair of stomach glands and a large hepatopancreas.

(i) *Stomach - gland.* It is a trilobed brownish gland and open into stomach. It secretes digestive enzymes like pepsin, lipase, eraspin etc.

(ii) *Hepatopancreas.* It is a large, brownish and lobulated gland occupies the entire preabdominal cavity. It has a mid-dorsal longitudinal groove in which lodges the heart. Intestine and other organs are found embedded in it. The wall of the lobules is composed of a layer of epithelium arranged on a thin membrane or tunica properia and a peritoneal covering. Two types of cells are found in the epithelium (a) large numerous absorptive cells and (b) fewer smaller ferment cells. Hepatopancreas sends 5 pairs of ducts open into the stomach.

Food and feeding. Scorpions are carnivorous and predaceous animals. They also practise cannibalism. They feed upon small animals like insects and spiders. The prey is sized and held by powerful chelate pedipalpi or being paralysed by the sting if the prey is large. The pedipalpi pass the killed prey to chelicerae which tear it to pieces. The food is then transferred to the pre-oral cavity which helps in squeezing the prey and oozing liquids are sucked in by the muscular pharynx. The process of feeding is very slow as the scorpion takes at least two hours to devour a cockroach. Scorpions can live without food for months together (about 6 months).

Digestion. Inside the preoral cavity the food is reduced to a pulp. Its proteins are partially digested by the secretion of certain alveolar glands which are present in the maxillary processes of first two pairs of legs. The food is reached to the stomach in partly digested state. Here the food is mixed with the secretion of stomach gland. The secretion contains pepsin, erepsin and lipase enzymes. Most of the digestion completed in stomach. In stomach hepatopancreas pour its secretion that contain anylase, lipase and proteinases enzymes. The digested food is absorbed into the absorptive cells of the hepatopancreas for storage. The food is sent to the intestine where water and remaining digested food material is absorbed. The undigested food is sent into the hindgut from where it goes out through the anus.

CIRCULATORY SYSTEM

In scorpions, the circulatory system is open type. It consists of:

I. Heart

II. Arteries

III. Sinuses

IV. Pulmonary Veins

V. Blood

I. Heart. The heart is an elongated and muscular tube of a faint greenish colour. It lies in the pre-abdominal region, just beneath the terga, in a deep median dorsal groove of the heptopancreas. The heart is divided from outside into seven chambers by shallow transverse constrictions. The heart has seven pairs of dorso-lateral and valvular apertures or ostia, each chamber possessing one pair.

The heart lies suspended by means of ligaments in a thin-walled, membranous sheath, the *pericardium.* Ligaments divide the pericardial cavity into four compartments: one dorsal, one ventral and two lateral.

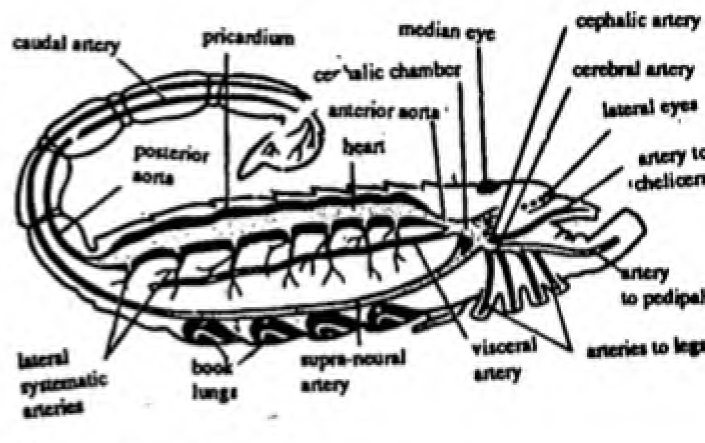


Fig. 59.8 *Scorpion.* Circulatory system.

II. Arteries. The heart is continued anteriosly as anterior aorta and posteriorly as posterior aorta. A series of paired lateral systemic arteries are also given off from the heart.

1. *Anterior aorta.* From anterior aorta a pair of *visceral arteries* are given off to the hepatopancreas and the intestine. After piercing the diaphragm it expands to form a small chamber behind the brain. The arteries to all the cephalic and thoracic appendages are given off from this chamber. It also gives off a pair of ventro-lateral arteries which curves round the oesophagus and unite to form the *supra-renal artery.* This artery runs behind above the ventral nerve cord and supplies posterior region of the body.
2. *Posterior aorta.* It is also known as caudal artery and arises from the posterior end of the heart. It lies on the dorsal side of intestine and supplies blood to the intestine, muscles, telson etc. It ends in poison glands.
3. *Systemic arteries.* A systemic artery is given off on either side of each chamber of the heart. They ramify to form a networks and supply the blood to different organs found in the abdomen.

III. Sinuses. The ultimate branches of arteries open into blood spaces or lacunae among the viscera. The blood from the lacumae is collected into five larger sinuses. Out of these, a *pericardia sinus* surrounds the heart, *drosal sinus* above *pericardial sinus,* two *lateral sinuses* are present on lateral sides and a large *ventral sinus* is situated on the ventral side.

V. Pulmonary veins. The oxygentated blood from each book-lung is carries by a pulmonary vein to the pericardial sinus.

VI. Blood. The blood of scorpions is slightly bluish due to the respiratory pigment haemocyanin dissolved in plasma. It contains many nucleated corpuscles. Blood transports food, oxygen, carbon dioxide, hormones and nitrogenous wastes.

Course of circulation. With the contraction of the ligaments, the cavity of heart enlarges and the blood of pericardial sinus passes on to the heart through ostia. Now the heart contracts, the ostia are closed and the blood is pumped to various organs of the body through the anterior and posterior aortae and the systematic arteries. The impure blood is collected in ventral sinus from where the blood is sent to the book lungs and is oxygenated. From book lungs pure blood is carries by pulmonary veins to pericardial sinus from where blood enters the heart through ostia.

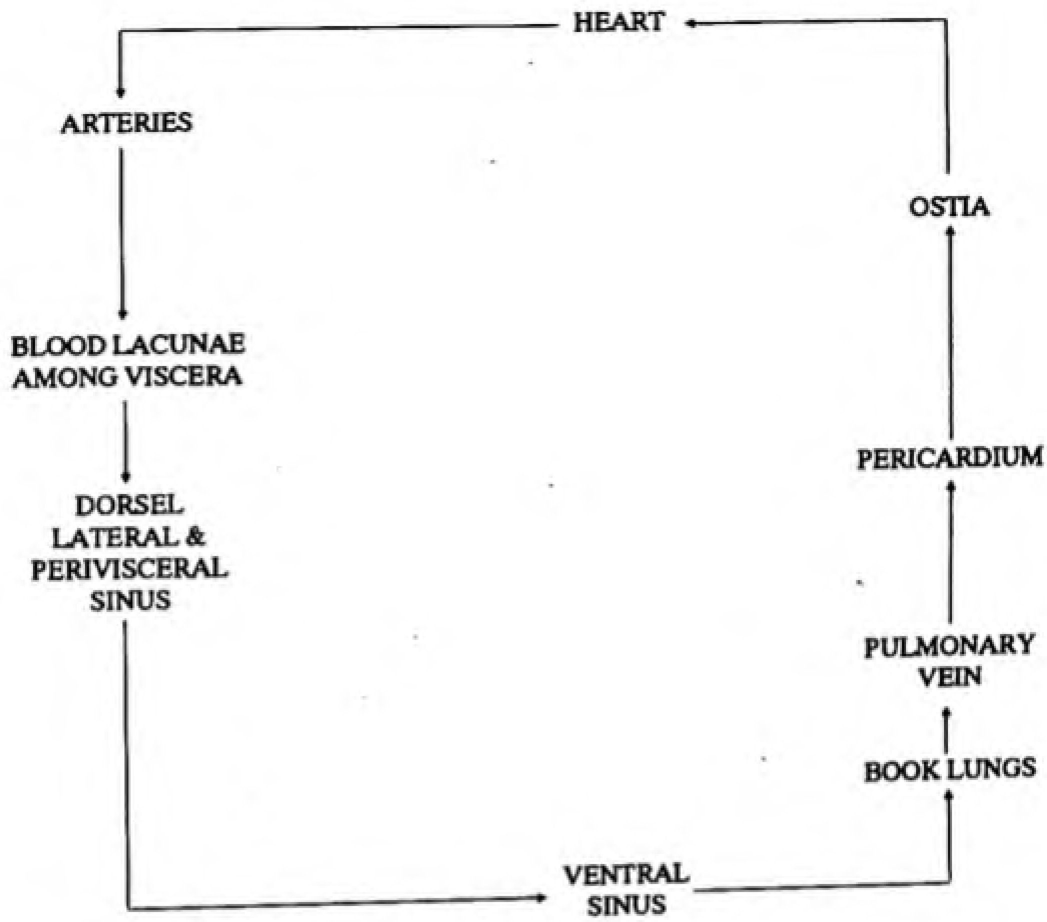


Chart Showing Course of Circulation in Scorpion

RESPIRATORY SYSTEM

The respiratory organs in the scorpion are book lungs. The respiratory system consists of 4 pairs of book lungs situated on the ventro-lateral sides of 3rd, 4th, 5th and 6th abdominal segments. Each book lung opens to the outside by a narrow slit- like aperture called stigmata.

The book lung is distinguished into two parts (i) Atrial chamber and (ii) Pulmonary chamber.

(i) *A trial chamber*. It is the ventral or proximal part of the book-lung. It is small and dorso-ventrally compressed and contains air. Its proximal and opens to outside by stigmata. There is a row of small pores called ostia in the roof of atrial chamber communicates with the interlamellar spaces of the pulmonary chamber through these ostia.

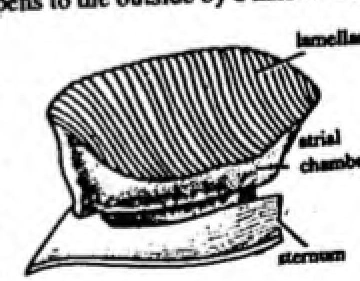


Fig. 59.9 *Scorpion* book being in dorsal view

(ii) *Pulmonary chamber*. It is the dorsal spacious oval chamber filled with about 150 vertical folds or lamellae, attached to the posterior side of the chamber. These are arranged parallel to each other and one over the other like the leaves of a book. Each lamella is a hollow structure formed of two thin layers of cuticle unites at their edges and thus enclosing interlamellar spaces filled with blood. The adjacent lamellae enclose interlamellar air spaces filled with

air. The interlamellar air spaces communicate with the atrial chamber through ostia.

Blood supply. The deoxygenated blood is sent to each book-lung from the ventral sinus by diverticulum, from where the blood gets filled in the intralamellar spaces of the lamellae. The aerate blood from each book-lung is drained by a pulmonary vein to the pericardium.

Mechanism of respiration. Air is drawn into and expelled out from the book-lungs by the action of dorso-ventral and atrial muscles. Contraction of these muscles compresses the book-lungs this expells out the foul air of the interlamellar spaces into the atrial chambers and than to the outside through the stigmata when these muscles relax, the pulmonary sac regains their normal shape as a result of which the fresh air rushes the atrial chambers through the stigmata and then fills the interlamellar spaces.

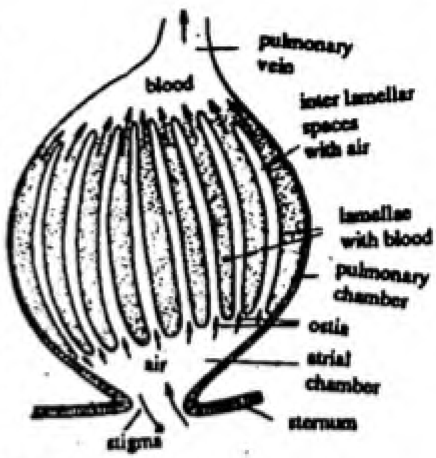


Fig. 59.10 *Scorpion*. V.S. of book lung.

The lamellae contain deoxygenated blood and are surrounded by fresh air. Thin walls of the lamellae permit the exchange of gases by diffusion. The blood takes up oxygen from air and gives up carbon dioxide to the air. The oxygenated blood and befouled air are then replaces and process is repeated.

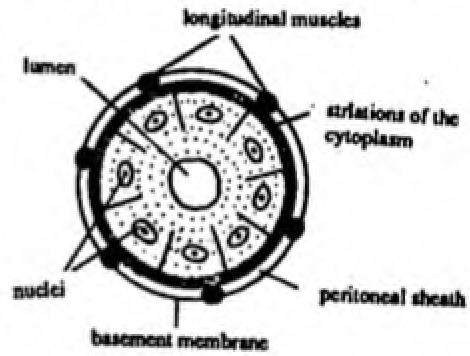


Fig. 59.11 *Scorpion*. T.S. of Malpighian tubule.

EXCRETORY SYSTEM

The excretory system of scorpion consists of

(i) Malpighian tubules

(ii) Coxal glands

(iii) Hepatopancreas

(iv) Nephrocytes

(i) Malpighian tubules. These are one or two pairs attached to the junction of mesenteron and hindgut. They float in blood from which they eleminate nitrogenous waste material and discharge it into the alimentary canal for elemination with the faeces.

(ii) Coxal glands. A pair of coxal glands is situated near the base of the 5th walking leg. Each consists of three parts: a large saccule or *end sac*, a long coiled duct or *labyrinth* and a small terminal *bladder* or *reservior*. The bladder opens outside by means of a minute pore situated on the posterior surface of the coxa of the fifth walking leg.

The coxal glands of scorpion are considered homologous with the antennary glands of prawn. The saccule and tubule of each coxal gland collect excretory nitrogenous wastes from blood and pass it out side through the excretory pore. Urate crystals are noticed in the saccule.

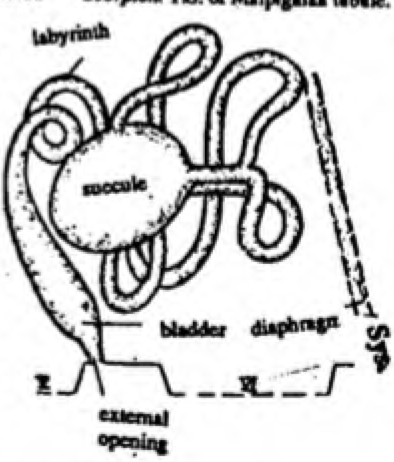


Fig. 59.12 *Scorpion*. Coxal gland.

(iii) Hepatopancreas. According to *Pavlovsky* the hepatopancreas of scorpions also serves as an excretory organ. According to him if ammonium carmine is injected in the body cavity of scorpion is collected in the form of small, bright, red granules by the cells of hepatopancreas.

(iv) Nephrocytes. Large nephrocytes and lymph tissue organs, present beneath the body wall in mesosoma, are both excretory as well as phagocytic in nature.

NERVOUS SYSTEM

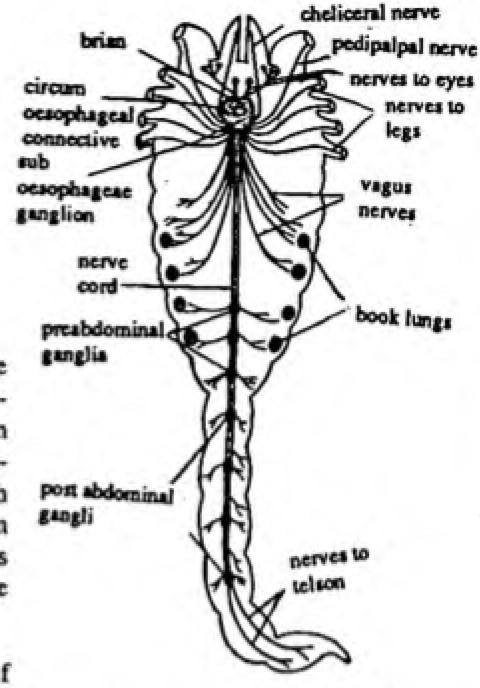


Fig. 59.13 *Scorpion*. Nervous system.

The nervous system consists of:

1. Brain or supra-oesophageal ganglion

2. Circum-oesophageal connectives

3. Sub-oesophageal ganglion

4. Ventral nerve cord

The brain is small bilobed mass situated in the prosoma just beneath the median eyes. From the brain arises a pair of thick, short and stout circum-oesophageal connectives which encircle the oesophagus and unite ventrally in a suboesophageal ganglion. The suboesophageal ganglion is continued backwards into the abdomen as double ventral nerve cord. It extends upto the 4th segment of the postabdomen. The nerve cord bears three segmental ganglia in the preabdomen and four in the postabdominal segments. The nerve cord is rounded and slender in the preabdomen but flatenned and ribbon shaped in the postabdomen.

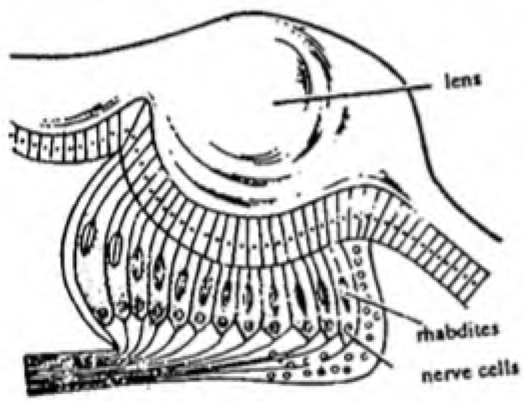


Fig. 59.14 *Scorpion*. V.S. of median eye.

Brain gives off a pair of optic nerves to the marginal eyes. Besides, the brain gives off numerous median delicate nerves to the rostrum, pharnyx and oesophagus. From the cerebral ganglion and circum oesophageal connectives arise six pairs of lateral nerves. These nerves innervate the six pairs of cephalothoracic appendages. The sub-oesophageal ganglion sends two to four pairs of vagus nerves. These run posteriorly into the preabdomen and supply the genital operculum, pectines and the first two pairs of book-lungs.

The segmental ganglia of the preabdomen sent out nerves to the last two pairs of book-lungs, heart and muscles of the abdomen. The segmental gnaglia of the postabdomen supply nerves to the segmental muscles. The last postabdominal ganglion also supplies the sting.

SENSE ORGANS

The sense organs of scorpion include the eyes and pectines.

1. **Eyes.** There are four pairs of eyes in scorpion - one pair of median eyes and three pairs of lateral eyes.

(i) *Median eyes.* Median eye is like a cup covered externally by a cuticular lens which is continuous with the cuticle but is much thicker. Inside the pigmented cup are rhabdomes, each enclosed inside several retinal cells which receive nerve fibres of an optic nerve.

(ii) *Lateral eyes.* These are similar to simple eyes of insects. These are like a pigmented cup covered externally by a biconvex lens formed from transparent cuticle. Within the

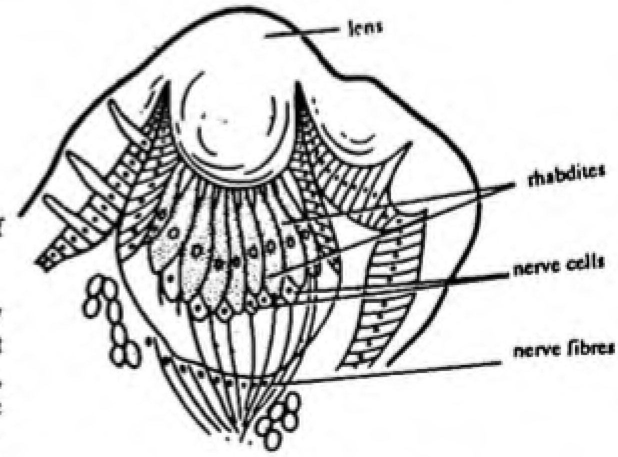


Fig. 59.15 *Scorpion*. V.S. of lateral eye.

cup are several longitudinal optic rods called *rhabdomes* associated with retinal cell or retinulae. The retinal cells receive nerve fibres.

2. **Pectines.** These are a pair of comb-like structures borne on the sternum of 2nd preabdominal segment. Their process have many sensory cells. They are tectile organs. They are also considered to be sensitive to the ground vibrations and changes in humidity.

It is also regarded that scorpions have some preception of sound. In some species of scorpions stridulating organs are found on the coxae of pedipalpi in the form of ridges, across which file-like surface can be drawn to produce some sort of sound.

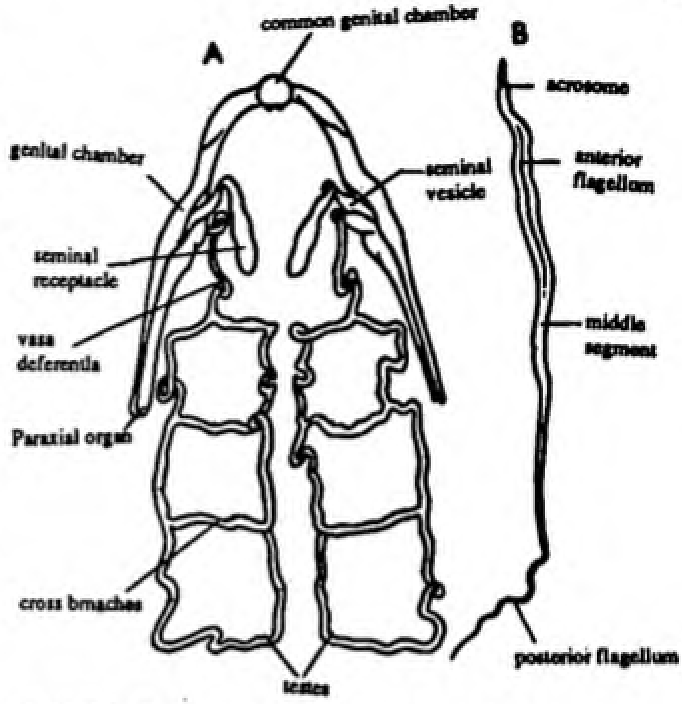


Fig. 59.16 *Scorpion.* A—Male reproductive organs, B—A sperm.

REPRODUCTIVE SYSTEM

The sexes are separate. Externally male and female are alike but they can be distinguished on the basis of following characters:

(i) The female is generally larger than the male.

(ii) The abdomen of female is broader than that of the males.

(iii) The pectines of female are smaller than of male.

(iv) The pedipalpi of female are smaller than those of male.

I. Male reproductive system. The male reproductive system comprises.

1. Testes
2. Vasa deferentia
3. Seminal vesicles
4. Accessory glands
5. Genital chamber
6. Paraxial organs.

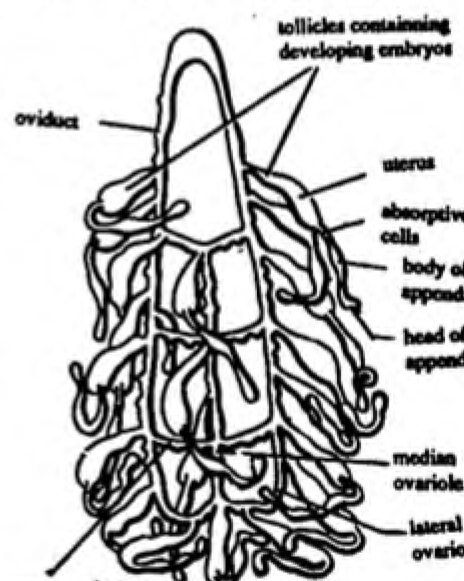


Fig. 59.17 *Scorpion.* Female reproductive organs.

1. *Testes.* A pair of tests are long mesh-like structure which lie embeded in the hepatopancreas from 3rd to 6th segment of mesosoma. A testis consists of two slender longitudinal tubules connected together by four transverse tubules so as to form three squares. Each tubule is lines with a layer of germinal epithelium. The cells of epithelium divide to form sperms which are filiform and motile.

2. *Vasa deferentia.* Anteriorly, a small thin duct arises from the other end of each testis. It runs forward and outward to atrium. Prior to its opening, it widens and this dilated part is known as terminal ampulla of vas deferens. The terminal ampulla receives the opening of accessory glands and the seminal vesicles.

3. *Seminal vesicle.* It is a small club-shaped structure which extends backwards from the terminal ampulla of vas deferens and opens into it. It acts as an organ of storage of mature spermatozoa.

4. *Accessory glands.* Four pairs of accessory glands are associated with the male reproductive organs. These are:

(a) Dorsal annex glands

(b) Ventral annex glands

(c) Oval glands

(d) Cylendrical glands

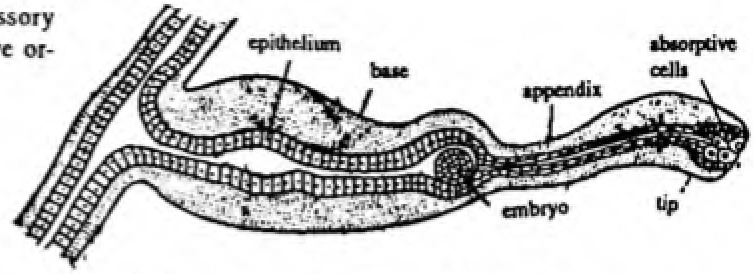


Fig. 59.18 *Scorpion.* Diverticulum of ovarian tubule.

The fluid secreted by all these glands collect in the terminal ampulla and helps is reproduction.

5. *Genital chambers.* The genital chambers are confined to the first and second mesosomatic segments. They extend obliquely towards the middle-line and open into the common genital chamber which opens out by means of male genital aperture which is situated on the ventral surface of the first mesosomatic segment and covered over by the genital operculum.

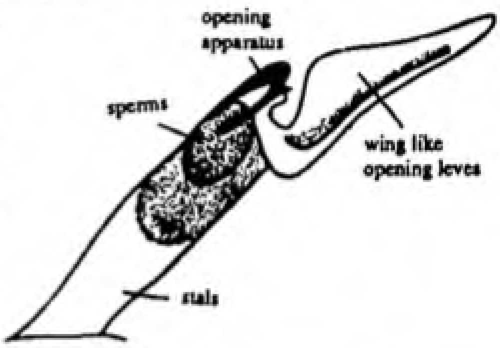


Fig. 59.19 *Scorpion.* A spermatophore.

6. *Paraxial organs.* Each genital chamber is produced behind into a paraxial organ which contains a tightly-fitting chitinous rod, the flagellum. The structure of the flagellum varies in different scorpions. It is provided with many spines and a longitudinal groove on the inner side. The two flagella together form the so- called double penis of the scorpions and they are said to evert out through the male reproductive aperture to serve as claspers during copulation.

II. Female Reprocutive Organs. The female reproductive organs comprise:

1. Ovary

2. Oviducts

3. Common genital chamber

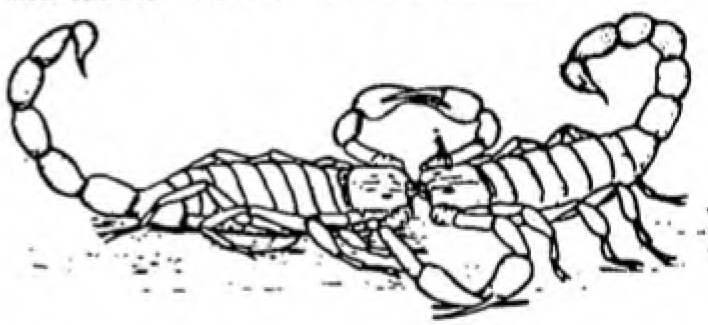


Fig. 59.20 Copulation in *Scorpions.*

1. *Ovary.* There is a single ovary in scorpion which extends from the 3rd segment to the 6th segment of the mesosoma. It remains embeded in the hepatopancreas. It consists of three long and narrow tubules called *ovarioles.* Of them the middle one is smaller and called median ovariole. The other two are long and present on the lateral sides and called lateral ovarioles. All the ovarioles are connected with each other at four places by transverse connectives giving a ladder like appearence. All the ovarioles and transverse connectives are lined with germinal epithelium, the cells of which divide to form ova. Many hollow sac-like structures, called follicles, arise from the ovarioles and the transverse connectives. Each follicle is male up of two parts a proximal swollen part, the *base* and a narrow distal part, the *appendix.* The tip of appendix enlarges to form the head. The development of embryos takes place within these follicles hence they are considered equivalent to the uteri of other animals.

2. *Oviducts.* A pair of tubes, the oviduct, starts from the anterior ends of the lateral ovarioles. These extend forwards for a short distance and then converge to open into a median sac, the genital chamber.

3. *Genital chamber.* The genital chamber is situated in the first mesomatic segment. It opens out side by the female genital aperture situated on the ventral side of first mesosomatic segment being covered by the bifid genital operculum.

Spermatophore. The sperms are transferred to the female by means of a spermatophore that is attached to the ground by a stalk. The spermatophore bears a wing-like lever at its free end. Connected to the lever is a pocket carrying sperms and also an opening apparatus. As the lever is pressed the opening apparatus is released and the sperms are triggered into the female genital

apertuse.

Copulation and fertilization. *Fabre* has described the mating habits of scorpion. Male and female face each other, raise their postabdomens high into the air, and move about in circles. The male then holds the pedipali of the female with his own peidpalpi and both interwine their postabdomens above them. They now walk together forward and backward and in rings. While moving in a ring, the male retreats, dragging the female after it. Courtship may last for hours or even days. Finally, the male digs a burrow and both enter it and mate. The male is often eaten up by the female after mating. Eventually the male deposits a spermatophore, that is attached to the ground. The male manoeuvres the female so that the genital area is over the spermatophore. The sperms enter into the female orifice and fertilization takes place. The Indian scorpions breed during monsoons.

Development. Development takes several months or even a year or more. The scorpions are *viviparous* and the mother gives birth to two or three dozens of young ones at a time. The egg is oval or spherical which is rich in yolk and is surrounded by a thin membrane lies in a follicle that arises as outgrowth of the walls of the ovariole or transverse connective.

After birth the young ones are carried by the mother scorpion on her back for some days till they can care themselves. Young ones moult several times before they grow into adults. Young ones than leave the mother and then become independent.

60

PERIPATUS

Peripatus or the "walking worm" belong to the small phylum Onychophora. Its position has been controversial in some texts Onychophora has been ranked as class where as in other as subphylum. In modern texts it is treated as a separate phylum that includes only about 70 living species. It has characteristics of both the Annelida and Arthropoda and is referred to as the "connecting link".

Historical account

Phylum Onychophora is represented by a single genus, *Peripatus* which was wrongly placed in phylum Mollusca by *Guilding* (1826) because of its slug-like appearence. But soon after the discovery of tracheae in the animal by *Mosely* (1874) it was classified as a class of phylum Arthropoda. *Sedgwick* has given a monograph on *Peripatus.*

Geographical Distribution

Peripatus is practically having its wide range of distribution both in tropical and subtropical areas. As it is shown in the table below, it is one of the best example of discontinuous distribution.

No.	Geographical distribution	Nomenclature given by *Sedgwick*	Name	No. of species
1.	Maxico and W. Indies.	*Neoperipatus*	*Peripatus*	29
2.	W. Africa and Congo.	*Congoperipatus*	*Mesoperipatus*	1
3.	Malaya	*Eoperipatus*		4
4.	S. Africa, Netal to Cape *Capoperipatus*	*Periperipatus*		7
5.	Malaya Penninsula	*Malayan Peripatus*	*Peraperipatus*	1
.6.	Australia, Tusmania,	*Austroperipatus*	*Parapaetoides*	
7.	New Zealand.			
8.	Chilli Island *Chiloperipatus*	*Chiliperipatus*		1
9.	Foot hill of Himalayas	*Yphelloperipatus*		1

HABITS AND HABITAT

Peripatus is exclusively a terrestrial and walking form and living in demp leaf moulds, barks of trees, under the stones, logs and in the cervices of rocks, but not in salt water medium.

They are nocturnal in habit, usually they come out at night for feeding. They are carnivorous and capture prey by shooting out a glue-like substance from openings on either side of the mouth. Small animals such as crickets and spiders quickly become entangled in the sticky glue.

EXTERNAL FEATURES

These individuals possess a reddish colour on the ventral side, while darker hues on the dorsal side. The body is cylindrically elongated, bilaterally symmetrical and small. It measures 1.5 - 15 cm in length, according to species. The skin is velvety, and thrown into transverse ridges bearing number of wart-like papillae furnished or armed into chitinous spines. Externally the body is not much marked segmented but each possess a pair of appendages.

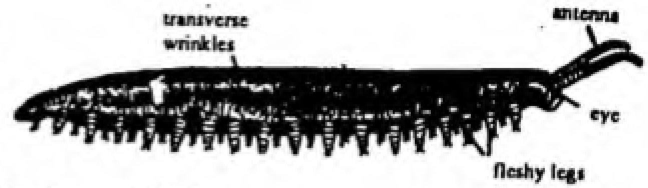


Fig. 60.1 *Peripatus.*

First three segments form head, which is not distinct. It bears a pair of segmented antennae, a pair of eyes situated dorsally. Mouth is midventrally situated bearing a pair of small horny jaws surrounded by a circular lip or circumoral fold and a pair of blunt oral papillae on either sides. Each oral papilla bears an aperture for slime gland which produce a sticky glue-like secretion for catching prey.

A secies of short, stumpy, conicasl legs arise ventro-leterally from the trunk. All the appendages are alike but for the last 2 or 3 are reduced. Their number varies from 14-43 pairs from one species to another. Each leg is short, unsegmented having tubercle and spiny pad on the ventral side. Each leg is hollow with terminal foot bearing a pair of curved claw.

Genital opening always lies infront of the anus which is situated at the posterior end of the body.

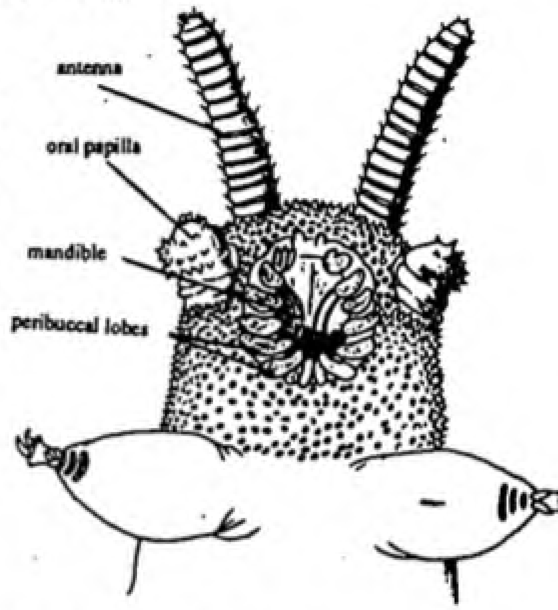


Fig. 60.2 *Peripatus.* Anterior region.

BODY WALL

The body wall is of annelidan type so the skin is formed of three layers, cuticle, epidermis and dermis. The exoskeleton is absent. The cuticle is thin flexible, chitinous and waterproof covering. It bears numerous velvety processes. It is secreted by cuticle. Beneath the cuticle is a single layer of epidermis, a thin basement membrane. The dermis is made up of connective tissue and their is a complex musculature composed of circular, longitudinal and transverse muscle layers. Beneath dermis is epithelial layer which lines the coelom or body cavity and invests the contained organs. By means of incomplete muscular partition the body cavity is divided into a median and two lateral compartments.

DIGESTIVE SYSTEM

The alimentary canal is simple and straight as in an annelid but the buccal cavity is formed secondarily by the union of a papillary ring and folds surrounding the true mouth into a circular lip. It contains a tongue and the jaws. Into the posterior end of buccal cavity there is a median opening of salivary glands. The salivary glands are elongated, narrow and tubular, representing modified nephridia. Buccal cavity follows a thick, muscular pharynx. Pharynx is followed by oesophagus a wide midgut and a short hind gut or rectum. The rectum opens out through the anus.

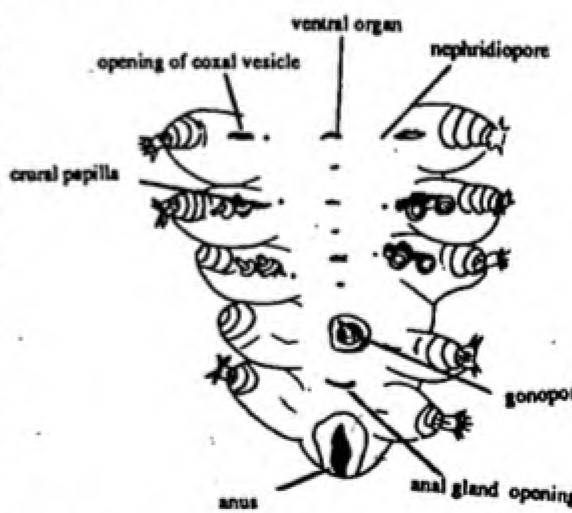


Fig. 60.3 *Peripatus.* Posterior region.

A pair of elongated and branches slime glands are present in the coelom. These open on the tips of oral papillae and secrete a glue-like adhesive substance which hardens on contact with the air. This secretion helps in catching the prey. Digestion is

inter-cellular takes place in midgut.

CIRCULATORY SYSTEM

The heart is an elongated muscular, mid-dirsal, contractile tube lying in the pericardial sinus. It is open at both the ends and bears several pairs of lateral ostia. Blood flows forward into various organs, there are no blood vessels to return the blood. The blood in collected into various sinuses and than pass to the heart.

RESPIRATORY SYSTEM

The respiratory system has delicate unbranched tracheal tubes internally lines by thin cuticle. These tubes expand in transverse plane through out the body and open externally by small pores called stigmata or spiracles. The stigmata lie in little dipressions of the integument, the tracheal pits. The number of spiracels varies from species to species, through these the air is drawn into the body.

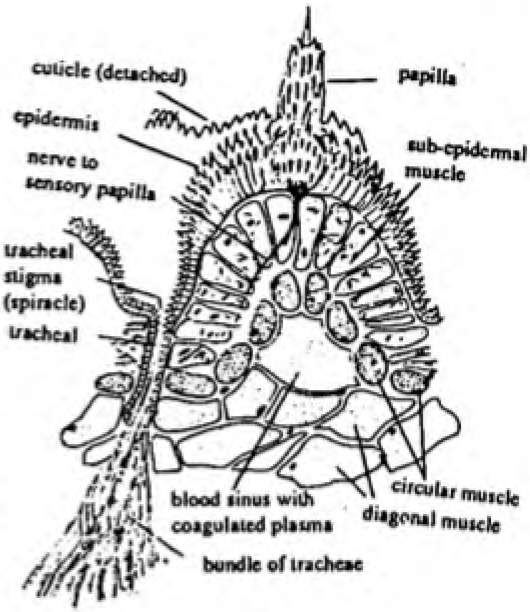


Fig. 60.4 *Peripatus*. Section of skin.

EXCRETORY SYSTEM

The excretory system is annelidean type which is effected by the segmentally arranged nephridia. A nephridium consists of distally a bladder extending into a coiled tube. It opens externally by nephridiopore situated at the base of leg. Internally it opens into colemic sac by a ciliated funnel. The bladder is originated from the ectoderm and the rest of the part from mesoderm. Other than nephridia there are coxal or crual glands lying in the lateral component of the body cavity whose ducts open on the lower surface of the legs just outside the nephridiopore. These glands are absent in females. The *Peripatus* is *uricotelic*, excreting chiefly uric acid an nitrogenous waste product.

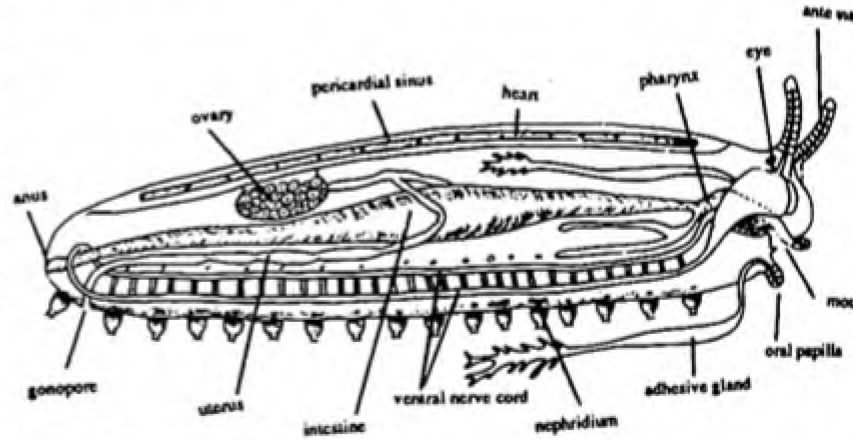


Fig. 60.5 *Peripatus* showing internal organ.

NERVOUS SYSTEM

The nervous system is primitive and is similar to that of annelids. It consists of two oval ganglia, the brain in the anterior part of the body lying over the pharynx. Two parallel longitudinal ventral nerve cords joined by many commissures assuming ladder-like in appearence.

EYES

The eyes are typical, resembling those of annelids in all respects. It is obvious when the animal is irritated their secretion is discharges in the form of fine viscid thread which might be the mesure of defence.

REPRODUCTIVE SYSTEM

The males are smaller than females. Sexes are separate and the reproductive ducts are ciliated. The gonads are paired and lie posteriosly above the intestine.

(i) **Male reproductive organs.** A pair of testes which each extend into a narrow tube-like vas eferens. Both the vasa efferentia

open into bulb-like structure, the seminal vesicles. Each vesicle is followed by vas deferens. The vasa deferentia are coiled structures and both unite to form an ejaculatory duct. The ejaculatory duct opens out through male genital pore. In connection with the reproductive system are crural glands found on all the legs except the first and are better developed in males. The sperms are glued together in ejaculatory duct to form spermatophore. The gonopore lies between the last pair of legs on ventral side.

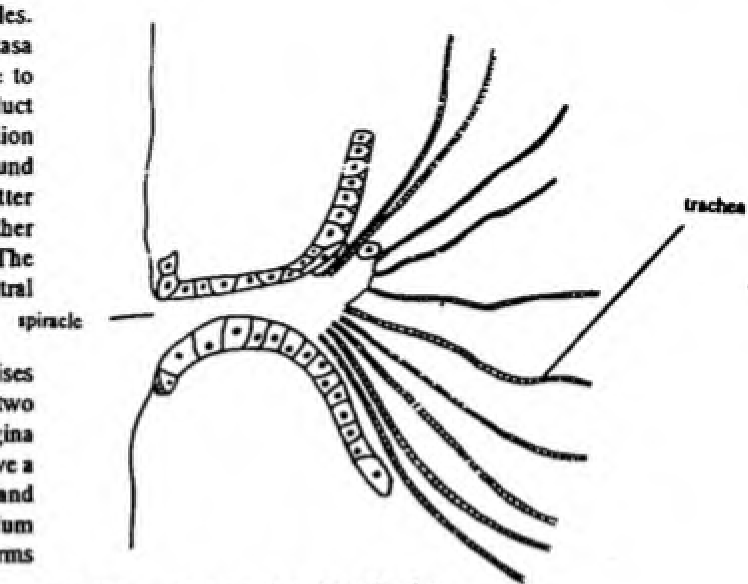


Fig. 60.6 *Peripatus*. Spiracle and Trachea.

(ii) Female reproductive organs. It comprises a pair of tubular ovaries, a pair of oviducts and two long uteri. Uteri unite behind into a median vagina opening into genital pore. Some species may have a seminal receptacle connected with the uterus and communicating with a funnel shaped recepticulum ovorum embracing the ovaries. In oviparous forms a long ovipositor is formed from the vagina.

Copulation. The real process of copulation is not yet observed and nothing is known about sperm enterance so far. The fertilization is internal sperms are not found in the uterus and oviducts so it appears probably that they reach directly to the ovary by boring through the skin or traversing the body cavity. Mostly they are viviparous but a few are oviparous. In viviparous forms embryos receive nourishment from the uterine wall through a placenta or they develop at the expanse of yolk. Oviparous forms lay eggs with advanced embryos. The young ones are alike to their parents except in size and colour. So that the mother does not appear to pay any special attention to her young ones, which wander away and get their own food.

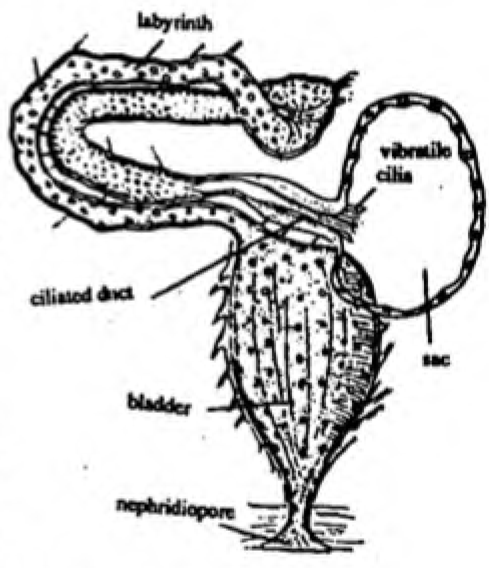


Fig. 60.7 *Peripatus*. A nephridium.

AFFINITIES

The Peripatus is very important from the zoological point of view because it displays some characteristics of annelids and some characteristics of arthropods along with some specialized features of its own. Because it shares the characters of two phyla, it is considered to be a connecting link between the two phyla showing that arthropods have arisen from annelids.

I. Resemblance with annelids

1. Body is vemiform, with truncated extremities.
2. True head is absent.
3. Body wall consists of a thin cuticle beneath which presence of circular and longitidunal muscles.
4. Eyes alike and simple.
5. Like the parapodia of annelids, the hollow, stumpy legs which are the extensions of the body wall.
6. Straight and simple alimentary canal.
7. Nervous system is primitive, originated from ectoderm.

8. Paired nephridia which are segmentally arranged.
9. Cilia are present in excretory and reproduction ducts.

II. Resemblances with arthropods

1. Antennae are present.
2. Jaws are nothing but modified appendages.
3. Locomotion by definit legs, having definit musculature and provided with claws.
4. Haemocoelomic condition is present similar to arthropods.
5. True coelom is reduced to the cavities of excretory and reproductive organs.
6. Respiration by tracheae.
7. Presence of peculiar salivary glands which are modified nephridia.
8. Cuticle has thin chitin deposition.
9. Structure of reproductive organs and development mainly arthropodan type.
10. The dorsal tubular heart communicating with pericardium by lateral ostia.
11. Absence of perivisceral section of coelom.

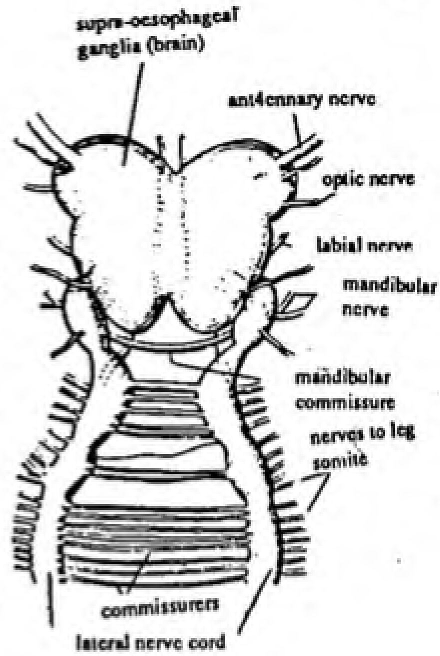


Fig. 60.8 *Peripatus*. Brain.

III. Its own Characters

Peripatus exhabit certain characteristics of its own to recognize it as neither an annelid nor an arthropod.

1. Absence of external segmentation of the body.
2. Valvety and soft nature of skin.
3. To some extent the antennae of *Peripatus* can not be homologous to that of other arthropods.
4. Nature of 3-segmented head seems to be mid-way of arthropods (head in made up of 6 segments).
5. Restriction of jaws to a single pair.
6. Quite unevenly distributed spiracles and tracheae.
7. Absence of true ganglia, but separate two ventral nerve cords.
8. Difference in the distribution of reproductive organs.
9. Structure of eyes is less complicated.

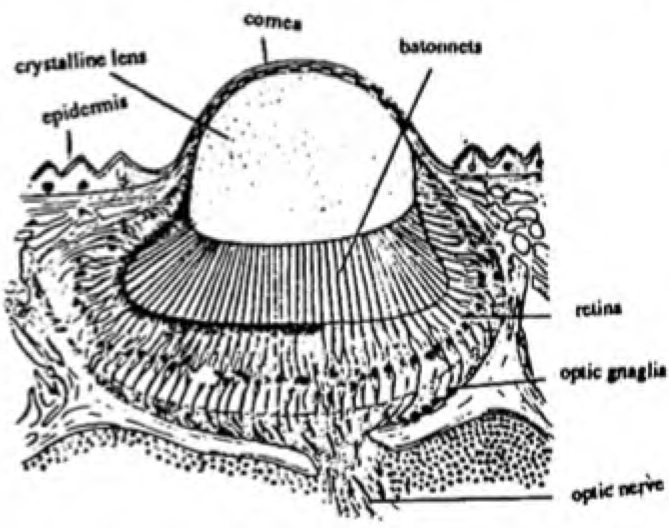


Fig. 60.9 *Peripatus*. V.S. of eye.

Taxonomic Position

With the peculiar nature and some annelidan characters it appears that probably annelids is one of the source and that it is originated from the marine polycheat, which given up the marine habit and has become modified for locomotion on the land without jointed appendages. It seems to be entirely against to the rest of the arthropods, yet it has been kept under phylum Arthropoda, giving it an separate class rank.

According to *Lankester* (1904), of aquatic region, the Hyparthropoda (a hypothetical undefined group presumably without

pre oral segments) were the first to appear and from these arose the protarthropoda with one pre-oral segment, a terrestrial discendent having survived as *Peripatus.*

According to *Menton* (1950-52) linkage of this group Onychophora with two phyla will not be probably evidence of simplification and moreover, the habitats of Onychophora provides ample reasons for the persistance of flexible body wall, leg like jaws together with the eloboration of a subcutaneous connective tissue instead of cuticular scutes.

According to *Snodgrass* (1938) the Onychophora and marine *Aysheaia* are possible discendantly from an extinct group of marine lopopod annelids and they may have no intimate relationship with trilobite chelicerate of precambrian arthropods. Onychophore bears chitinous mandibles which only might be preserved as fossil nothing of other parts known so far due to its soft nature.

No doubt the *Peripatus* is a living example and strictly terrestrail, and the only fossil refered to the class have been quesationed. Of these *Aysheaia* from middle Cambrain is the best known fossil. It was a marine form, probably devoid of tracheae. Moreover, 10 pairs appendages but these bear with 6 claws, while the recent onychophores bear only two claws on their legs. It seems obvious that this *Aysheaia* may represent a very primitive onyhophore which is more closer to the annelids than the arthropods.

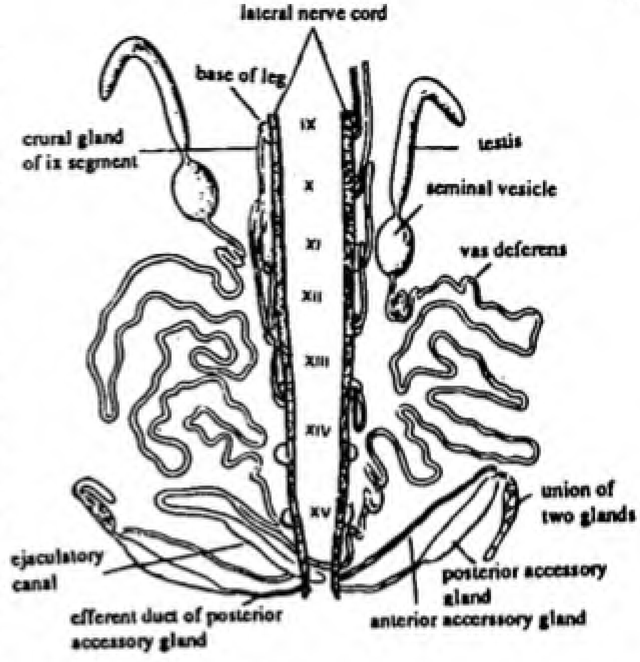


Fig. 60.10 *Peripatus.* Male reproductive organs.

Apart from that it must have been derived archiannelidian stock because of the ventral nerve cords were primitive, widely separated conditions or it may more be correct to say that the present day annelids and *Peripatus* have got their origin from a common ancestor from which they independently evolved.

It is due to because that common features appeared between the onychophores and present day annelids are similar, being evolved from common ancestral stock in which such characters were probably present.

Common ancestor of
Onychophora and archiannelids

modern arthropods — Modern onychophores — Modern annelids — Archiannelids.

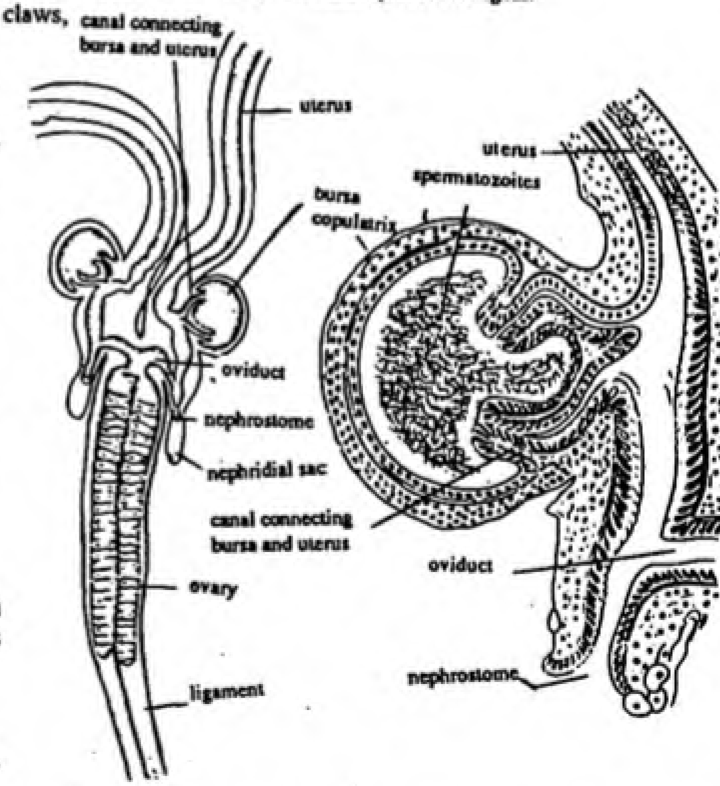


Fig. 60.11 A—Female reproductive system of *Peripatus trinitatis*, and B—Longitudinal section through bursa copulatrix (*after* Gaffron).

However, according to modern concept (based on *Barnes*, *Marshall* and *William*) this group was more wide spread and diversified. The view is supported by its discontinuous distribution and discovery of several fossils from middle cambrian. It is, therefore, believed that onychophora is an ancient independent group of segmented animals contemporary to arthropods and as such has been placed under separate phylum onychophora.

CHARACTERS & CLASSIFICATION OF MOLLUSCA

Members of the phylum Mollusca are among the most conspicuous invertebrates and include such familiar forms as clams, oysters, squids,octopods and snails.during the last 18th and 19th centuries, when natural history, occupied the time of many well to do gentlemen, shell collections were as popular as today.such collections,often containing species gathered from various parts of the world, have contributed considerably to our knowledge of the phylum. In abundance of species, molluscs comprise the largest invertebrate phylium aside from the arthropods. Over 100,000 living species have been described. In addition, some 35,000 fossil species are known.

The term Mollusca (L. *mollis* = soft) mean soft bodied and for the first time coined by *Aristotle* in his famous *Historia Animalium* to describe various kinds of cephalopods and gastropods. the term Mollusca was used by *Jonston*(1650) to include cephalopods and Barnacles.

The classification of Mollusca divided into the five classes-Amphineura, Gastropoda, Lamellibranchia and Cephalopoda, by *Laseneer* (1992) has remained standard ever since.

CHARACTERS

1. Some are aquatic, mostly marine, a few fresh water and some terrestrial forms.
2. Symmetry bilateral, viscera and shell coiled in Gastropoda and some Cephalopoda.
3. The body is triploblastic made up of 3 germ layers.
4. Body without any appendage and segmentation.
5. Body skin single layered mostly ciliated and with mucous glands.
6. Body usually small and soft and enclosed in an en velop, the *mantle* that secretes shell of various shape and sizes.
7. Generally the body is divided into 4 parts, the visceral mass carrying the vital organs of the body; the head, anterior most part bearing mouth, eyes and tentacles nbut is absent in the *Pelecypoda* and the *Scaphopoda*, the foot a muscular mass, the form and function of which varying in the different classes and lastly the mantle or pallium a thick muscular clock covering the entire animal.
8. Shell, when present, usually univalve, consituting an exoskeleton, internal in some.
9. Coelom reduced and represented mainly by pericardial cavity, gonadial cavity and kidney.
10. The alimentary tract is either straight or coiled. Jaws are present in many, especially in gastropods and cephalopods. In most of animals a rasping organ, the radula appears in the buccal cavity. the radula tears up the food.
11. Blood vascular system consists of dorsal heart with 1 or 2 auricles and 1 ventricle and is of open type.
12. Respiration by general body surface or mantle or by one to many gills or a lung in the mantle cavity.
13. Excretion by paired metanephridia (kidneys).
14. Nervous system of paired ganglia, connectives and nerves. Ganglia usually form a circumenteric ring.
15. Sense organs include eyes, statocysts and receptors for touch, smell and taste.

16. Sexes are usually separate (some hermaphrodite a few protandric); gonads 2 or 1 with ducts; fertilization external or internal. Mostly oviparous, few viviparous.

17. Development direct or interrupted with larval, stage, the veliger larva of mollusca. The asexual reproduction is completely absent.

Phlyum Mollusca is divided into six classes. Monoplacophora, Amphineura, Gastropoda, Scaphopoda, Pelecypoda and Cephalopoda.

CLASS 1 MONOPLACOPHORA

1. Abyssal or fossil, from lower Cambrain to Devonian, probably carnivorous.
2. Bilaterlly symmetrical and metamerically segmented, but segmentation internal.
3. Shell dorsal and consisting of a single piece (hence Monoplacophora).
4. Mantle covering the dorsal surface of body.
5. Foot is ventral with a flat creeping sole.
6. Mouth is anterio-median and the anus is posterio-median.
7. Head is without eyes.
8. 5 or 6 pairs of gills externally and serially arranged.
9. Six pairs of nephridia and two pairs of gonads.
10. Stomach contains a crystelline style and the animal feeds on radiolarians.
11. Nervous system primitive, lacks ganglia.
12. Sexes are separate.
13. Development is indirect with a trochophore larva.

    Example: *Neoplina galatheae*.

CLASS II AMPHINEURA

(Gr; *Amphi*= both; *neuron*= nerve)

1. Most primitive molluscs with either elongated and vermi-form or dorso-ventrally flatenned body.
2. Head indistinct and without eyes and tentacles.
3. Foot broad, flat,sole-like and ventral in position.
4. Shell and mantle covering the body from dorsal and lateral sides.
5. 6-60 pairs of gills situated laterally in the pallial cavity on either side of foot. They may be reduced to one pair.
6. Mouth and anus at the opposite ends of body.
7. Nervous system primitive and ladder-like with or without ganglia.
8. Heart with one or two auricles.
9. A pair of nephridia connected to the pericardium.
10. Sexes separate or united.

Class Amphineura is divided into two orders:

Order - 1. Aplacophora

1. The body is long, narrow, worm like.
2. The shell is absent.
3. Mantle containms tiny calcareous spicules.
4. Foot is reduced or absent.
5. Heart consists of a single auricle and a ventricle.
6. Gills are absent or reduced to a pair located in the cloacal cavity.
7. Alimentary canal is straight without redula.
8. Nervous system with a distinct brain and ganglia.
9. Sexes united.

   Examples: *Chaetoderma,Neomenia.*

Order - 2. Polyplacophora

1. Body elliptical, convex dorsally and flatenned ventrally.
2. Shell dorsal and formed of eight calcareous pieces.
3. Mantle with spicules disposed along the margins.
4. Gills 6 to 8 pairs, present in the pallial groove on the lateral sides of foot.
5. Head devoid of eyes and tentacles.
6. The whole ventral surface is occupied by the broad and flat foot.
7. Alimentary canal is coiled with well formed redula.
8. Heart with two auricles.
9. Nervous system without definite ganglia.
10. Sexes separate.

    Examples: *Chiton,Chaetopleura.*

CLASS -III- GASTROPODA

(Gr. *Gastros*= stomach; *podos* = foot)

1. Body is asymmetrical with a mantle and shell.
2. The shell is univalved and spirally colied.
3. Head is distinct bearing tentacles, eyes, and a mouth.
4. Foot is ventral and muscular.
5. Visceral mass usually coiled exhibiting various types of torsions.
6. Anus usaully situated anteriosly close to the mouth.
7. Buccal cavity contains an odontophore with a redula.
8. Respiration is carried on by integument or gills or lungs.
9. Circulatory system open type with dorsal heart enclosed in pericardium.

10. Excretory system includes one or two kidneys or nephridia.
11. Nervous system contains distinct cerebral, pleural, pedal, parietal and visceral ganglia.
12. Sexes are separate. Mostly oviparous, a few viviparous.
13. Development indirect with veliger and trochophone larval stages.

Class Gastropoda is divided into three sub-classes. Prosobranchia, Opisthobranchia and Pulmonata

SUBCLASS (A) PROSOPBRANCHIA (STREPTONEURA)

1. The visceral nerve commissures are twisted into a figure of 8, hence the name streptoneura (Gr. *streptos* = curved,*neuron* = *nerve*). This is due to torsion.
2. The mental cavity containing the pallial complex opens anteriorly.
3. The gills or ctenidia, if present, lie in front of the heart hence prosobranchia.
4. Head has a single pair of non-retractile tentacles.
5. Calcarious shell with an operculum.
6. Sexes are separate.
7. Exclusively marine.

Subclass Prosobranchia is divided into three orders: Archaeogastropoda, Mesogastropoda and Neogastropoda.

Order - 1. Archaesogastropoda (Aspidobranchia)

1. Due to incomplete atrophy of organs, the kidneys, auricles, nephridia and ctenidia are paired.
2. Ctenidia are bipectiante or plume like.
3. Ospheridium poorly developed.
4. The nervous system is little concentrated.
5. Gonad opens into the right kidney serving as gonoduct.
6. Fertilization external.

The order has been distinguished into the following two subroders:

Surborder (i) Docoglossa

1. Shell and visceral mass conical.
2. Ctenidium single or absent or replaced by secondary gills.
3. Radula with three marginals on either side.
4. Auricle single.

Examples: *Patella, Acmaea*

Surborder(ii) Rhipidoglossa

1. Shell spiral.
2. Ctenidia paired.
3. Radula with numerous marginals.

Examples: *Haliotis, Fissurella, Trochus.*

Order - 2. Mesogastropoda (Pectinibranchia)

1. These are advanced snails with complete atroply of the left side so that usually unpaired auricle, nephridium, ospheridium and ctenidium occur.
2. Ctenidium monopectinate or comb-like, attached to the mantle throughout its entire length.
3. Edge of the shell opening lacks a siphonal notch oor canal.
4. Foot may be operculate.
5. Ospheridium pectinate and well differentiated.
6. The nervous system is concentrated.
7. Gonad has its separate duct and opening.
8. Fertilization internal. Development is indirect with free-swimming veliger larva.

   Examples: *Pila, Triton, Valvata, Natica, Vermetus.*

Order - 3. Neogastropoda (Stenoglossa)

1. Carnivorous species with an eversible proboscis.
2. Ospheridium is large and bipectinate.
3. Foot operculate.
4. One gill with filaments in one row, heart with one auricle, single nephridium present
5. Nervous system is lightly concentrated.
6. Shell has a siphonal canal.
7. Embroys are intracapsular. Free swimming veliger surpressed.

   Examples: *Murex, Oliva, Magilus.*

SUBCLASS (B) OPISTHOBRANCHIA (EUTHYNEURA)

1. Due to detorsion of visceral mass, visceral loop becomes untwisted hence named (Gr.*euthus* = straight, *neuron* = nerve).
2. Mantle cavity displaced posteriorly.
3. Head with two pairs of tentacles.
4. Shell and operculum, if present, reduced.
5. Usually one auricle and one nephridium present.
6. Ctenidia are replace by secondary gills.
7. Hermaphroditism is universal. Larva is veliger.
8. Exclusively marine.

   Subclass Opisthobranchia is divideed into eight orders as follows:

Order - 1. Cephalaspidea

1. These are borrowing forms having shield like head.
2. Shell and mantle cavity moderately developed.
3. Lateral parapodial lobes are prominent.

   Examples: *Bulla, Acteon.*

Order - 2. Anaspidea

1. These are crawling or burrowing forms having a pair of rhinophores on head.
2. Shell is small and internal.
3. Mantle cavity is reduced on right side.
4. Parapodial lobes are prominent.

   Examples: *Aplysia, Akera.*

Order - 3. Thecostomata

1. These are shelled pteropods.
2. shell is spirally coiled or a non-spirally pseudo-conch.
3. Mantle cavity is well developed.
4. Parapodial fines are large.

   Examples: *Cline, Limacina.*

Order - 4. Gymnostomata

1. These are naked pteropods and planktonic.
2. Shell and mantle cavity absent.
3. Small ventral parapodial fins are present.

   Example: *Pneumoderma.*

Order - 5. Notaspidea

1. Shell is external or reduced and internal.
2. Mantle cavity is absent, but a skirt-like projection of mantle covers gill on the right side.

   Example: *Pleurobranchus.*

Order - 6. Acochlidiaceae

1. Small without shell and gill.
2. Naked visceral mass projecting behind the foot and covered with spiracles.

   Examples: *Acochlidium.*

Order - 7. Saccoglossa

1. These are herbivorous, with a modified redula and suctorial pharynx.
2. They are shelled or naked slug-like, with a gill.

   Examples: *Elysia,Oxynoe.*

Order - 8. Nudibranchia (Acoela)

1. They are naked bilaterally symmetrical sea-slugs without shell, mantle cavity ctnedia and ospridium.
2. They have secondary gills around anus or surface outgrowths or cerata.

   Examples: *Doris, Aeolis, Tritonia .*

SUBCLASS (C) PULMONATA

1. The ctenidia are absent and replaced by pulmonary sac or lung.
2. Shell is simple spiral or vestigial or absent and operculum never occur.
3. One or two pairs of tentacles and one pair of eyes are present.
4. The torsion takes place. The nervous system is secondarily symmetrical due to shortening of connectives and concentration of ganglia into a circumoesophageal ganglionic complex.
5. The heart with a single auricle lying anterior to the ventricle.
6. The animals are bisexual. Gonad single.
7. Development direct without larval stage.

   The subclass is divided into two orders:

Order - 1. Basommatophora

1. One pair of tentacles with the eyes at the base.
2. Shell is delicate with a large aperture.
3. Some forms with secondary gills.
4. Male and female gonopores usually separate.

   Examples: *Lymnaea, Planorbis, Physa.*

Order - 2. Stylommatophora

1. Two pairs of retractile tentacles. Eyes are lodged on the tip of posterior pair of tentacle.
2. Shell is internal, reduced or absent.
3. Mostly terrstrial.
4. Male and female gonopores usually united.

   Examples: *Helix, Limax, Arion.*

CLASS. IV. PELECYPODA

1. The pelecypods or bivalvia are marine or fresh-water, bilaterally symmeteical molluscs.
2. Mntle consists of paired right and left lobes, which secrete a bivalved shell.
3. Devoid of head, eyes, tentacles and redula.
4. The muscular foot is usually wedge-shaped or tongue-shaped, which is adapted for burrowing.
5. Presence of two gills, one on either side of mantle cavity, the function of which is to produce respiratory and food-carrying currents of water.
6. Pharynx is absent.
7. Coelom is reduced to a dorsal placed pericardium.
8. Alimentary canal is coiled with a large paired digestive glands.
9. Heart is continued with pericardium and comprises two auricles and one ventricle.
10. The renal organs are a pair of coelomic kidneys, which lead into pericardium at one end and to outside at other.
11. The nervous system includes four pair of gaanglion, viz., cerebral, pleural, pedal and visceral.

12. Sense organs are statocyst and osphradium.
13. Sexes may be separate or united. Development includes metamorphosis, followed by trochophore stage.

Class - Pelecypoda is divided into following orders:

Order - 1. Protobranchiata

1. Presence of paired plume-shaped gills, each bears two rows of filaments.
2. The foot is flatenned.
3. Presence of anterior and posterior adductor muscles.
4. Sexes separate, gonads lead into kidneys.

Examples: *Nucula, Solenomya.*

Order - 2. Filibranchiata

1. Single pair of plate-like gills formed of distinct V-shaped filaments.
2. Inter-filamentar junctions are either absent or formed by groups of inter-locking cilia.
3. Inter-lamellar junctions are either absent or non-vascular.
4. Two adductor muscles present, anterior may be redused or absent.
5. Foot small or poorly developed.,

Example: *Mytilus, Arca, Noah.*

Order - 3. Pseudolamellibranchiata

1. The gills are plaited so as to present vertical folds.
2. Inter-filamentar junctions may be ciliary or vascular. Interlamellar junctions may be vascular or non-vascular.
3. Shell valves are frequently unequeal and single large adductor muscle present.
4. Foot is little developed or rudimentary.
5. Genital organs open into kidneys or near them.

Examples: *Pecten, Ostrea, Pinna, Lima.*

Order - 4. Eulamellibranchiata

1. Gills are basket like, the gill-filaments are attached with vascular inter-filamentar and inter-lamellar jinction.
2. Gills may be smooth or plaited.
3. Two equal adductor muscles.
4. Foot is well developed.
5. Siphon of small or large sized present.
6. Gonads open out by separate openings. They do not open into kidneys.

Examples: *Unio, Teredo, Anodonta, Venus, Cardium, Mya.*

Order - 5. Septibranchiata

1. Gills replaced by horizontal muscular and perforated septa dividing the mantle cavity into upper and lower chambers.
2. Foot long and slender, byssus reduced or absent.

3. Adductor muscles two.
4. True ctenidia are absent.

   Examples: *Cupisdaria, Poromya.*

CLASS -V. SCAPHOPODA

1. They are aberrant marine animals comprising onlyof three genera.
2. Body is elongated worm-like, enclosed in a tusk-like shell open at both ends.
3. Eyes, tentacles and gills are absent.
4. Mantle tubular completely enclosing the body.
5. Mouth surrounded by lobular processes or outgrowths.
6. Foot is reduced used for digging.
7. Heart rudimentary.
8. Sexes are separate.
9. Torsion takes place in some forms.

   Scaphopoda has two families:

Family (i) Dentalidae

1. Foot is trilobed having two epipodial lobes and one hypopodial lobe.

   Examples:*Dentalium, Antalis.*

Family (ii) Siphonodentalidae

1. Foot is elongated and capable of expansion into a terminal disc.

   Examples: *Pulsellum, Siphonodentalium.*

CLASS - VI CEPHALOPODA

1. Exclusively marine.
2. Shell spiral chambered or usually with or without shell embedded in mantle.
3. Body with head and trunk. Head bears eyes and mouth.
4. Trunk consists or symmetrical and uncoiled visceral mass.
5. Mantle encloses posteriorly and ventrally a large mantle cavity.
6. Foot altered into a series of sucker beaaring arms of tentacles encircling the mouth.
7. Mouth bears jaws and radula.
8. Two or four pairs of bipactinate gills.
9. Circulatory system closed, heart with two or four auricles.
10. Excretory system comprises two or four pairs of nephridia.
11. Nervous system is highly developed and the principal ganglia are concentrated around the oesophagus.
12. Sexes are separate.
13. Development meroblastic without metamorphosis.

14. Most of the cephalopods have an ink-gland with a duct opening into the rectum.

    Cephalopoda is divided into three subclasses:

SUBCLASS (A) DIBRANCHIATA

1. The foot modified into a circlet of eight to ten arms bearing suckers, around the mouth.
2. The funnel forms a complete tube.
3. The shell is generally internal.
4. Presence of paired gills and kidneys.
5. Presence of characteristic ink-gland and duct.

   Dibranchiata is divided into two orders.

Order - 1. Octopoda

1. Body rounded or oval and with no lateral fins.
2. Arms eight, long arms or tentacles absent.
3. Suckers on the arms sessile and without horny rim.
4. Shell and cnidamental glands absent.

   Examples: *Octopus*(Devil-fish), *Agronauta*

Order - 2. Decapoda

1. Body elongated and with no lateral fins.
2. Arms ten, eight short and 2 long and known as tentacles.
3. Suckers on the arms sessile and without horny rim.
4. Shell internal and well developed.

   Examples: *Sepia, Loligo.*

SUBCLASS (B) NAUTILOIDEA OR TETRABRANCHIATA

1. The foot divides into lobes bearing numerous tentacles.
2. The funnel is incomplete.
3. Shell is external which is divided into several compartments.
4. Kidneys and gills are four.
5. Devoid of ink gland.
6. Pericardium communicates to the exterior directly.
7. Eyes simple without crystelline lens.
8. Chrometophore, salivary glands absent.

   Examples: *Nautilus.*

SUBCLASS (C) AMMONOIDEA

1. All are extinct.
2. Shell variously modified in the form of straight spiral or turreted.

3. Siphon external, siphuncle simple and marginal.
4. Two pairs of ctenidia.

   Example: *Ammonities.*

CHAETODERMA

Phylum	-	Mollusca
Class	-	Amphineura
Subclass	-	Aplacophora
Genus	-	*Chaetoderma*

1. It is a most primitive mollusc.The body is worm-like cylindrical. it is found around North Atlantic.
2. The head is separate off from the body by a constriction.
3. Mantle covers the body completely.
4. Shell is absent but the body is covered by numerous calcareous spicules.
5. Rudimentary foot.
6. Gills reduced to a pair which are situated in the cloacal cavity.
7. Sexes are seperated and each has one fused gonad.
8. A cavity is present at the posoterior end of the body into which opens the anus.

Fig. 61.1 *Chaetoderma*

PATELLA

Phylum	-	Mollusca
Class	-	Gastropoda
Subclass	-	Prosobranchia
Order	-	Aspidobranchia
Suborder	-	Docoglossa
Genus	-	*Patella*

1. *Patella* or limpet is a littorral and is found attached to the rocks.
2. It is found along Pacific coast, Atlantic coasyt,Europe, U.S.A.
3. Body is oval with convex dorsal surface.
4. Shell is oval and core-like, with a conical projection from its dorsal surface.
5. Operculum is absent.
6. The head is laterally produced into aa pair of small, stout, tectile tentacles.
7. Eyes are simple prersent at the base of tentacles.
8. Foot ventral and sole-like for creeping.
9. True mantle is restricted to the anterior and secondary mantle cavity is developed between foot and mantle.

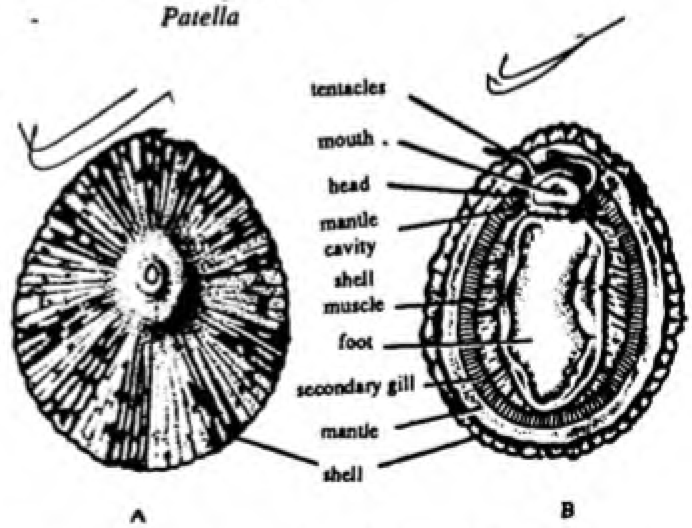


Fig. 61.2 *Patella.* A—Dorsal view, B—Ventral view

10. Redula composed of very few, strong hooked teeth in each rew.
11. All around the foot lies a secondary pallial cavity containing a series of secondary branchiae.
12. Heart with single auricle.
13. Herbivorous, feeding upon alage, sea-weeds and diatoms.
14. It is eatrn by poor classes in country like France, Italy and Ireland.

HALIOTIS

Phylum	-	Mollusca
Class	-	Gastropoda
Subclass	-	Prosobranchia
Order	-	Aspidobranchia
Suborder	-	Rhipidoglossa
Genus	-	*Haliotis*

1. *Haliotis* or 'Ear shell' is marine and found attached to rocks and feeding on sea-weeds and other marine vegetation.
2. The animals are very common at and below low tide level.
3. *Haliotis* or *Abalone* has ear-shaped shell with small flatenned spire.
4. The aperture is very large and without operculum.
5. The shell is perforated by a series of marginal slits through which project the tentacular processes of the mentle.
6. The foot is large and with epipoidia and the animal can move 2to 4meters per minute but clings very powerfully to the boulders.
7. Eyes are borne on stalks at the outer bases of the tentacles.

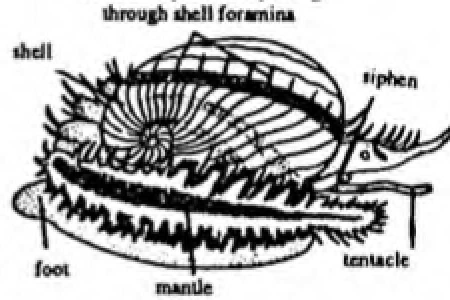


Fig. 61.3 *Haliotis.*

8. The mantle cavity is large, has bipectinate ctenidia or gill, the right being smaller.
9. The shell of the animal is of great economic importance, as beautiful pearly buttons are manufactures from the shell of *Haliotis* in Europe and U.S.A.
10. The animal is also eaten in countries like China, Japan and many cities along the Pacific coast.

MUREX

Phylum	-	Mollusca
Class	-	Gastropoda
Subclass	-	Prosobranchia
Order	-	Pectinibranchia
Genus	-	*Murex*

1. It is a marine animal found between low tide marks on stones and sea weeds.
2. It is founded on the Syrian coast, Italy, India; West Indies and U.S.A.
3. Shell is spirally coiled and with three or more rows of beautiful spines of different lengths.
4. It is carnivorous and highly predator feeding on living animals which it grasps by means of its foot. It is destructive to oyster bed.

Fig. 61.4 *Murex.*

5. A very prominant bipectinate osphradium perist.
6. Head is prolonged into a long probosics which can be retracted within the probocis- sheath.
7. Adrectal glands present which secrete a dye the *Jyrain purple*(Yellow in colour).
8. Sexes are separate.

APLYSIA

Phylum	-	Mollusca
Class	-	Gastropoda
Subclass	-	Opisthobranchia
Order	-	Anaspidea
Genus	-	*Aplysia.*

1. It is a marine animal found among sea-weeds.
2. It is found in India, Asia, West Indies and on the Florida coast.
3. It is commonly called 'sea hare'.
4. Body is soft, lumpy with a visceral hump.
5. Head with two pairs of tentcles. The anterior pair is large and ear-like, the posterior pair is olfactory and bear eyes at their base.
6. Shell thin, reduced and trnsparent, enclosed by mantle.
7. The foot is muscular and elongated pointed posteriorly with lateral out growths, the parapodia.
8. Mantle possesse unicellular ink glands secrete purple ink, used for defence.
9. Hermapherodite.There is a single generative aperture and a single duct for the sperm and ova but a seminal groove runs from the aperture to the head and reciprocal fertilization is impossible.
10. Nervous system is well developed with perfectly symmetrical visceral loop.

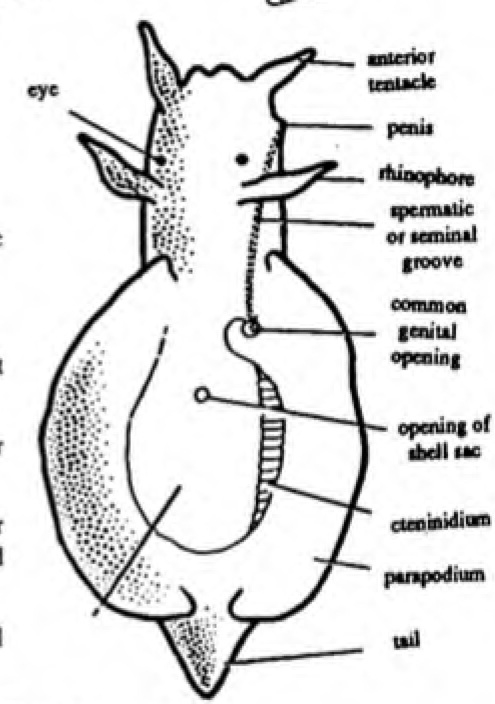


Fig. 61.5 *Aplysia.*

AEOLIS

Phylum	-	Mollusca
Class	-	Gastropoda
Subclass	-	Opisthobranchia
Order	-	Nudibranchia
Genus	-	*Aeolis*

1. It is a marine slug-like gastropod found in shallow waters crawling on under surface of sea weeds.
2. Found in U.S.A.,Europe.
3. *Aeolis* is a small nudibranch 1 or 2 cm in length.
4. The soft body is covered with a transparent integument.
5. The shell, mantle and true gills are absent.

6. The cerata are the respiratory organs.
7. There are cylindrical extensions of the integument, containing hollow extensions of the liver and nematocyst derived from ingested hydroids.
8. The cerata have characteristic arrangement, may occur in many transverse or in few longitudinal rows.
9. The head is small, bears tentacles, usually two pairs, one which may be retractile.
10. The anterior or oral pair is the longer.
11. The posterior or dorsal pair, known as rhinophores bear simple sense organ with test the surrounding water.
12. At the base of each rhinophore is an eyespot.
13. The mouth is prominent and can be most easily seen from the ventral view.
14. On the right side of the head is conspicuous genital opening.
15. Just posterior and dorsal to genital opening lies the small anus.
16. On the ventral side the animal has a highly muscular foot.

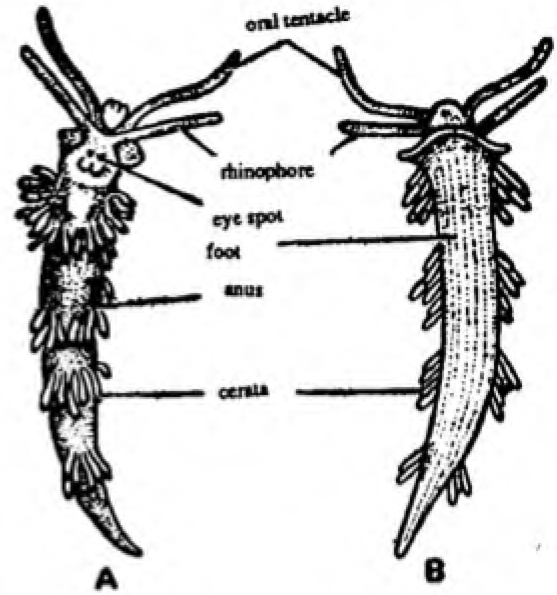


Fig. 61.6 *Eolis.*

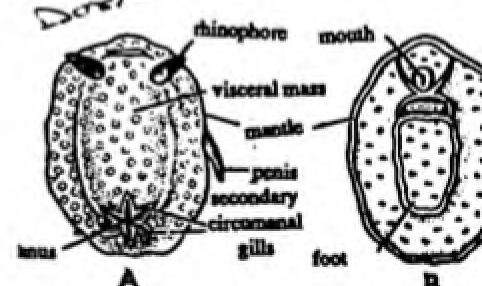
17. Proportion varies with the species.
18. Mouth is guarded by lips which cover both the radula and the horny jaws within the buccal cavity.
19. The powerful jaws cut the hydroid into two pieces. The *Aeolis* is hermaphroditic and gonad is protandric.

DORIS

The systamatic position is same as that of *Aeolis*

1. It is a sluggish marine animal found under stones at low tide marks.
2. It is cosmopolitan in distribution.
3. It is commonly known as 'sea lemon'.
4. The body is oval and depressed ,concave abopve and flat below.
5. Head is indistnict , but there is a pair of short olfactory tentacles or rhinophores towards the anterior end.
6. Mantle is usually pigmented and contains calcareous spicules or dorsal tubercles.

Dorsal view



Ventral view

Fig. 61.7 *Doris.*

7. Mouth is present on ventral side. Anus lies mid-posteriorly and is surrounded by a circlet of feathered retractile secondary branchiae.
8. The broad foot is on ventral side.
9. Hermaphrodite, gonopore is asymmetricelly placed on the right side of the body.
10. *Doris* has undergone *detorsion*, therefore, the shell, mantle cavity and primary gills are absent.

LIMAX

Phylum Mollusca

Class	-	Gastropoda
Subclass	-	Pulmonata
Order	-	Stylommatophora
Genus	-	*Limax.*

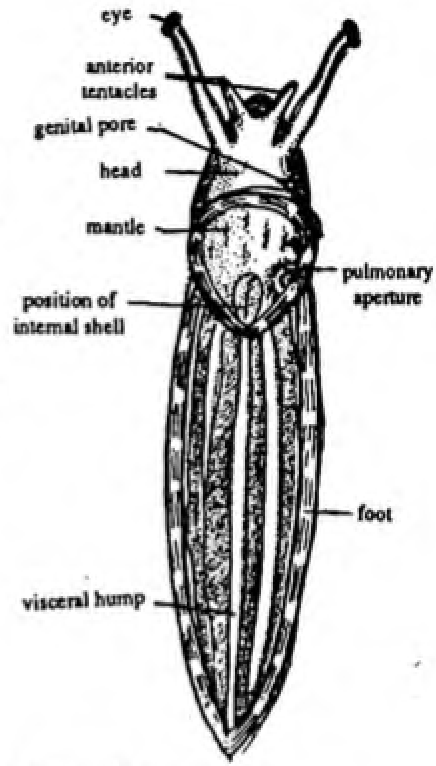


Fig. 61.8 *Limax.*

1. It is a terristial gastropod, found in gardens over damp soil.
2. It is cosmopolitin in distribution.
3. It is commonly known as 'gray slug'.
4. Body is elongated and tapering behind and is divisible into head, foot and visceral hump.
5. Two pairs of retractile tentacles are present on head. Eyes are present at the tips or posterior tentacles.
6. The mouth is on the ventral side of the anterior end and is bounded by a pair of lateral lips.
7. Mantle forms aa sheild like area in the dorsal side of the anterior part of the body. The mantle cavity acts as a lung for the breating, pneumostome, present on right side.
8. Shell is internal, thin and rudimentry, lies embedded in mantle.
9. Foot is on ventral side.
10. A pedal gland just behind the head for the mucous secretion.
11. Bisexual.
12. Nocturnal and herbivorous.

HELIX

The systematic position is same as that of *Limax*.

1. It is a terrestrial animal found in damp places, under bark and fallen leaves.
2. It is found in Palearctic region.
3. It is commonly called 'garden snail'.
4. The shell is thin, external and heliciform with a low conical spire, measuring 4 cm. in length.
5. Head bears two pairs of tentacles, first pair bears organs of small and second pair is large and bears a pair of simple eyes.
6. Foot possesses a flat ventral surface for creeping.
7. Respiration by pulmonary sac.
8. Gills are absent.
9. Hermaphrodite. the genital aperture opens above the right lateral lip. Gonads contain four angled dark and multifid digitiform glands.

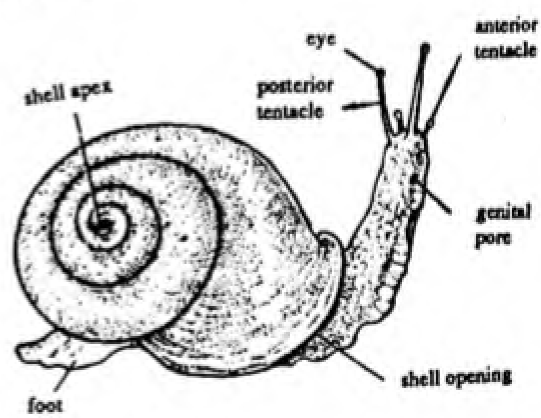


Fig. 61.9 *Helix.*

MYTILUS

Phylum Mollusca

Claass	-	Pelecypoda
Order	-	Fillibranchia
Genus	-	*Mytilus*

1. It is a marine, sedentary mollusc found at a depth of 2 or 3 fathoms in low tide mark, attached to rocks or wooden structure by its byssus threads.
2. It is commonly called as 'sea mussel' and cosmopolitan in distribution.
3. The shell is elongated, equivalent with umbo at or near anterior end.
4. Hing toothless but may bear cerculations.
5. The foot is tongue-like and is modified into a bunch of byssal threads coming out from between the two shell-valves, which are main anchoring orgns.
6. The anterior adductor muscle is weaker where as posterior is strongly developed.

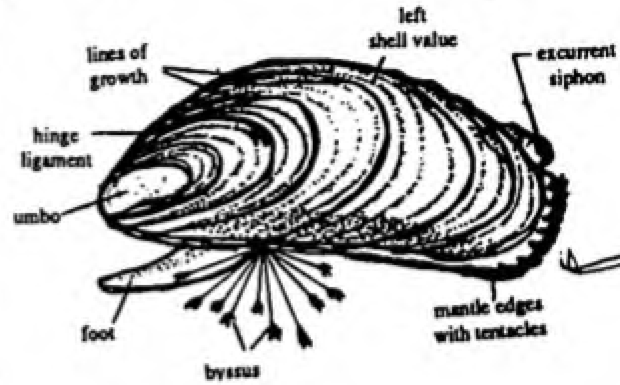


Fig. 61.10 *Mytilus.*

7. A pair of gills is present each gill is provided with gill-filaments. the gill are lamelliform.
8. The eyes are found anterior to the inner gill-lamella.
9. Sexes are separate. Gonads extend into the mantle.
10. It is used s food in Europe.

PECTEN

Phylum	-	Mollusca
Class	-	Pelecypoda
Order	-	Pseudolamellibranchia
Genus	-	*Pecten*

1. It is free swimming marine mollusc lives on the sea bottom of 10 fathoms deep.
2. It is found in India and U.S.A.
3. It is commonly called as scallop.
4. Two shells are uniqual. The right shell being larger and more convex and the animal rests on this valve.
5. There is a single large adductor muscle.This is divided into parts and the larger of these served for rapid contraction which cause swimming movements.
6. Foot is very much reduced but in larva very well developed and used for locomotion.
7. Two large and crescentric gills are present.
8. Mantle is *tentaculiferous* and it encloses viscra.

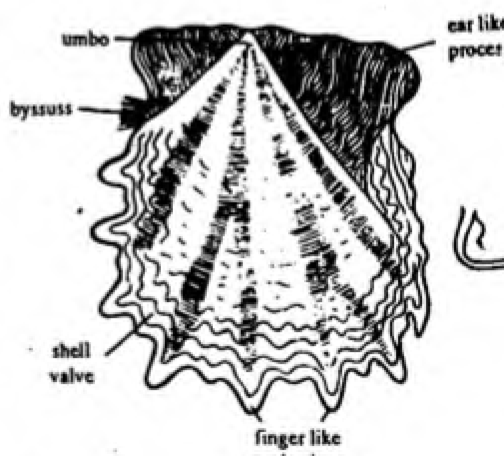


Fig. 61.11 *Pecten.*

9. Large number of stalked eyes are present at regular intervals along the edges of the mantle.
10. These are hermophrodite.

11. The ovary has pink colour when eggs are ripe.
12. The testis lies behind and is cream in colour.

OSTREA

The systematic position is same as that of *Pecten*.

1. It is a sedentary bivalve attached to rocks or other shells and found in shallow and brackish water.
2. It is found in Atlantic and Pacific coasts India, Gulf of Mexico to Massachusetts.
3. It is commonly called 'edible oyster'.
4. The shell valves are unequal, the left is always larger and permanently attached to the rocks by byssus.
5. Only one adductor muscle i.e. posterior one. It is divided into two parts one is straited and other is non-straited.
6. The foot is absent.

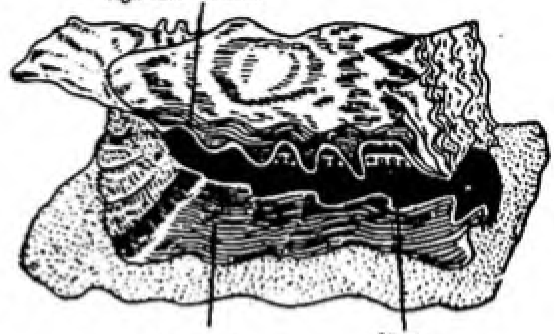


Fig. 61.12 *Ostrea*

7. Heart with two fused auricles.
8. A pair of curves gills present.
9. It is peculiar in the sense as the individuals function alternately as males and females.
10. Spawning genearlly takes place at full moon. The eggs develop into vileger larva which metamorphoses into adult.

TEREDO

Phylum	-	Mollusca
Class	-	Pelecypoda
Order	-	Eulamellibranchia
Genus	-	*Teredo*

1. Marine pelecypod which burrows in wood of the boats, ships and other submerged wood.
2. It is found in India, Europe, Cape Cod to Florida and Massachusetts Bay to Florida.
3. It is commonly called 'shipworm'.
4. *Teredo* has body extremelly elongate and worm-like appearance.

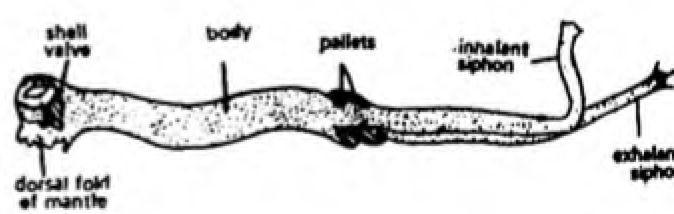


Fig. 61.13 *Teredo*.

5. Foot reduced.
6. Mantle tubular and opens anteriorly, shell is reduced and covers only the anterior part of the body.
7. The mantle cavity and shipons are long and the latter unites to a large extend and provided with calcareous pallets for protection.
8. A constant current into and out of the mantle cavity is maintained by ciliary action.
9. The saw duct is swallowed by the animal and is digested by cellulose digesting enzymes.

SOLENOCURTUS

Phylum	-	Mollusca
Class	-	Pelecypoda
Order	-	Eulamellibranchia
Genus	-	*Solenocurtus*

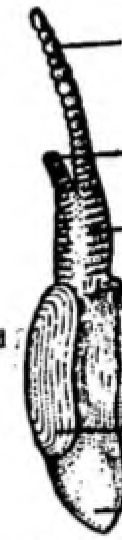


Fig. 61.14 *Solenocurtus* (Razor-fish).

1. It is a burrowing pelecypod found in India and U.S.A.
2. It is commonly called 'razor fish' or 'razor shell'.
3. Bivalve shell, mantle divides into right and left lobes.
4. Body is laterally comopresed and bilaterally symmetrical.
5. A pair of basket-shapedd gills consisting of filaments, whcih are united by interfilamentar and inter-lamellar junctions.
6. Two equal-sized adductor muscles developed.
7. Presence of two elongated siphonal tubes which are united with each other.
8. The shell has the appearance of long scabbard.
9. The foot is long, cylindrical and enormously developed which is capable of penterating into the loose sand.

OCTOPUS

Phylum	-	Mollusca
Class	-	Cephalopoda
Subclass	-	Dibranchia
Order	-	Octopoda
Genus	-	*Octopus*

1. It is marine and cosmopolitan in distribution generally found on the Atlantic and Pacific coasts.
2. It is commonly called devil fish.
3. Body surrounded by mantle containing chromatophores. They can change their colour according to surrounding medium.
4. Foot modified into eight equal arms surrounding the head and siphon.
5. The arms are beset with suckers which are sessile and without horny rims.
6. Body is covered with tubercles, short, round aborally and without fins.
7. External shell is absent and body with vestiges of an internal shell.
8. Third arm on the right side in male modified to act interomittent organ or hectocotylized.
9. Like *Sepia and Loligo, Octopus* is also capable of producing inky liquids which form a smoky screen water.
10. Sexes are separate and there is no metamorphosis as the development is direct. Female cares the eggs.
11. Mouth with sharp and beak-like horny jaws.

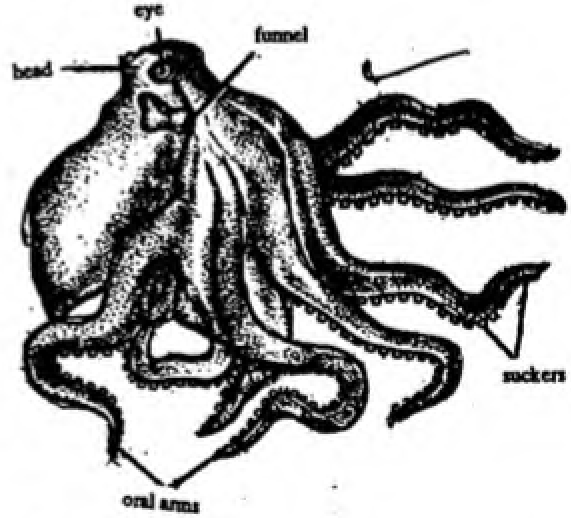


Fig. 61.15 *Octopus*.

ARGONAUTA

Phylum	-	Mollusca
Class	-	Cephalopoda
Subclass	-	Dibranchia
Order	-	Octopoda
Genus	-	*Argonauta.*

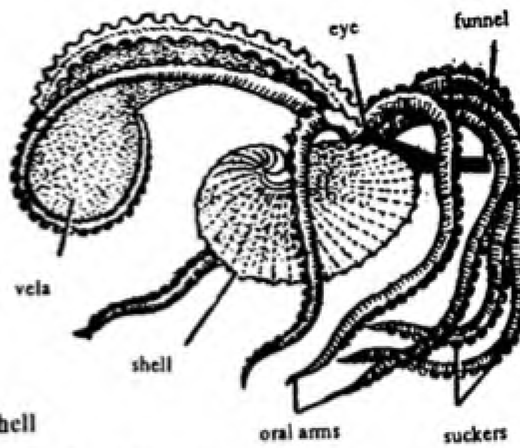


Fig. 61.16 *Argonaura.*

1. It is a marine animal found in Atlantic and Indian oceans.
2. It is commonly called as 'paper nautilus'.
3. Sexual dimorphism is remarkable and well-marked.
4. Male in 2.5 cm in length and without shell.
5. Female is 20 cm in kength and possesses a thin, transparent shell secreted by the extrimities of two dorsal arms.
6. Shell is used for protection of eggs.
7. Third arm in male is hectocotylized.
8. Eyes and funnel and present.
9. Two plume-like ctenidia and two kidneys are present.

NAUTILUS

Phylum	-	Mollusca
Class	-	Cephalopoda
Subclass	-	Tetrabranchia
Genus	-	*Nautilus*

1. It a marine cephalopod living in shallow wters and shores and coral reefs in the Indian and south Pacific Oceans.
2. It is commonly known as 'Pearly nautilus'.
3. The shell is well developed, spirally coiled and composed of calcareous matter, which is divided into several compartments by a series of septa.
4. Through the various compartments runs a tube called siphuncle the walls of whcih are formed of calcium carbonate. A narrow vascular prolongation of visceral region of the animal passes through this tube.

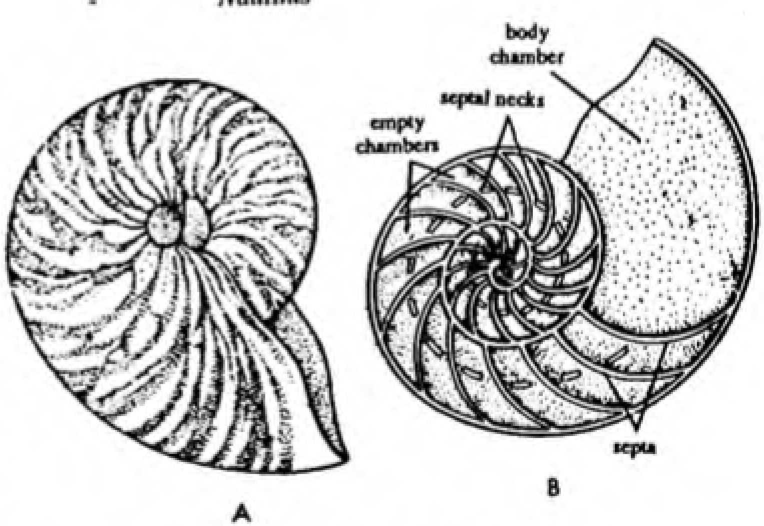


Fig. 61.17 *Nautilus.* A—External shell, B—Internal chamber.

5. Head is well developed bearing the eyes.
6. The anterior part of foot is modified into several arms provided with tentacles which are arranged in two series.
7. The posterior portion of the foot is modified into funnel situated below the head.
8. Buccal cavity with a pair of jaws and odontophore bearing several teeth.
9. Two pairs of gills and kidneys are present.

10. They are hyper-polyandrous i.e. male are abundant than female.
11. Presence of 60 tentacles in male and 90 in female.
12. Pericardium leads directly to exterior by two orifices located near the posterior renal aperture.

PILA GLOBOSA

Pila is commonly called as 'apple snail'. It comes under class Gastropoda. The gastropods have undergone an extemsive adaptive radaition and have in vaded various kinds of habitats.

SYSTEMATIC POSITION

Phylum	-	Mollusca
Class	-	Gastropoda
Subclass	-	Prosobranchia
Order	-	Pectinibranchia
Genus	-	*Pila*
Species	-	*Globosa*

DISTRIBUTION

The genus *Pila* is restrivted to the Oriental and Ethiopoan regions. In the Oriental region it occurs in India (except the province of Punjab), Burma, Ceylon, Thailand, Malaya, Vietnam,Indonesia and Philippines and in the Ethiopian region, in Africa, Arabia and Madagascar. *Pila globosa* is the common species found in North India except Punjab.

HABITS AND HABITAT

These are largest known fresh water snails. They inhibit ponds, tanks, paddy-fields and sometimes in fresh water rivers and in brackish water.They occur in those areas where there is a large amount of vegetation like *Vallisneria or Pistia*, foor food. They are amphibious being adapted for life in water as well as on land. They make long journeys on land in search of areas with more abundant food and water during rains. The animal creeps by its ventral muscular foot they pass over long periods of drought by remaining *torpid* with the aperture of shell tightly by the operculum.

EXTERNAL FEATURES

Shell. The body of *Pila* is enclosed in a calcareous shell, which is somewhat conical and is coiled dround a central axis, the coils, or whorls being marked off externally from each other by distinct sutures.

The top of the shell is distinguished as the *apex*.Below this are distinguishable the successiive lines called *sutures* running a spiral course. The lowermost whort is considerably bigger than all the other whorls taken together, and ends in a wide opening, the mouth or aperture. In the living animal, the aperture is directed forwards and ventrally and the apex points backwards. The internal cavity contained in the shell, is a continuous one running through all the whorls. The margin of the aperture is named the *peristome*; its outer part is called the *outer lip* and the inner part, the *inner lip* or the *columellar lip*.

The axis of the shell or the *columella* is hollow and its cavity opens to outside by an opening called *umbilicus*, whϕich lies close to the left corner of the inner margin of the peristome. Into the aperture fits an oblong flat plate, called *operculum* which is composed of materiaal secreted by certain glandular cells of the foot. The inner and outer surface of the operculum bear characteristic markings.On its inner surfaces stands out a sharp elliptic impression, called the *boss* which is produced by the attachment of the *opercular muscle*. Round the boss runs a groove. The outer surface of the operculum is marked by a number

of lines of growth running round a *nucleus* which is situate subcentrally near the inner margin.

Microscopic structure of the shell. The shell of *Pila* consists of three layers. The outerlayer is known as *periostracum*. It is greenish brown. The underlying two layers are made up of *calcareous plates*. In the *ostracum*, the middle layer, the calcareous plates run at right angles to the margin of the aperture of the shell. *Ostracum* is the thickest of the three layers.In *hypostracum*, the innermost layer, the plates are arranged parallel to the margin of aperture. The structure of the two inner layers is similar, but the calcareous plates in the two zones lie at right angles to one another.

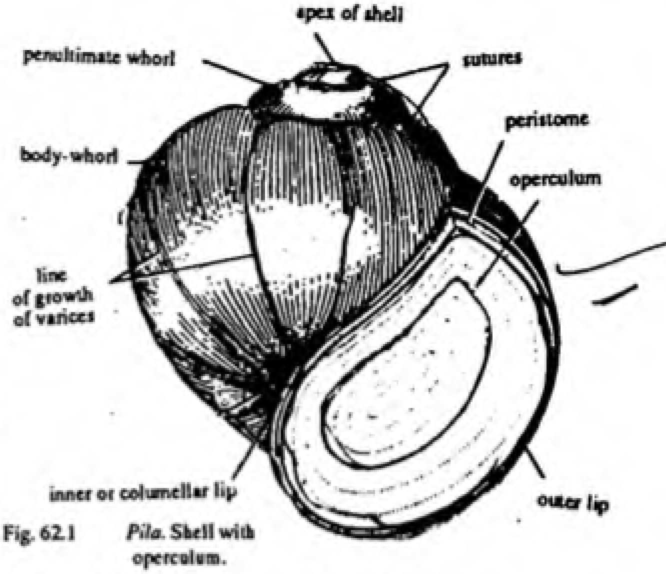


Fig. 62.1 *Pila*. Shell with operculum.

Body. The body of the animal is firmly attched to the shell by means of the *columellar muscle* which arise from the foot and in inserted on the columella. On removal from the shell the body can be distinguished into foot, head and visceral mass. The head and foot are bilaterally symmetrical while the visceral mass is asymmertical.

Head. The anteriormost part of the body, overhanging the foot, forms a definite head. It bears dorsally a pair of small tapering and contractile *first pair of tentacles or labial palps*. The snout bears the mouth iiin its anterior surface below the palps. Behind the labial palps are the longer, filament like *true tentacles* or *second pair of tentacles*. These are hollowed and very contractile and become about 5 cm. long when fully extended, but only 1.5 cm. when contracted. The eyes are placed on tips of short stalks or *ommatophore* which arise from the outeer sides of the tentaacles near their bases. On the two sides of head connecting it and mantle, occur two fleshy structures, which are called *nuclial lobes* or *pseudepipodia*. The left nuchal lobe is bettrer developed and forms the *respiratory siphon*.

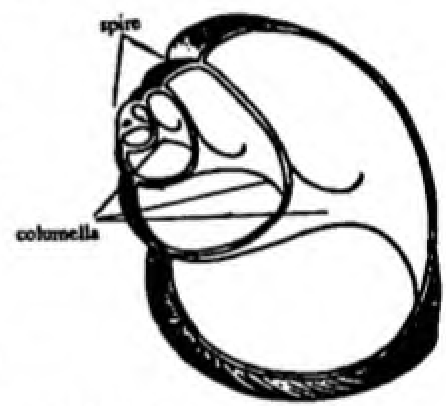


Fig. 62.2 *Pila*. Shell in section.

Foot. The large, strongly muscular, ventral part of the body forms the *foot*. When fully expanded, it is roughly triangular in shape, with the apex directed backwards. The foot has a broad, flat, smooth and grey ventral surface, or the *sole*, for creeping. The foot bears the *operculum* dorsally on its posterior end, called the *operculiferous lobe*. When the foot is withdrawn, the operculum completely fits into the mouth of the shell and closes it.

The head-foot complex is attached to the visceral mass by a short inconspicuous *neck*.

Visceral mass. The visceral mass is a spirally coiled hump-like strucctture on the dorsal side and ontains all the vital organs of the body.

Mantle. The skin of the *visceral mass* from the *mantle* or the *pallium*, the characteristic mollusca structure. The free edge of the mantle is thickened and possessese the shell-secreting glands. The mantle keeps a regular check over the anterior part of animal. There is a long, narrow *supramarginal groove* along the thick free edge of the mantle. Behind the *supramarginal groove*, there is a slight, thickend band, which has the shell-secreting glands.

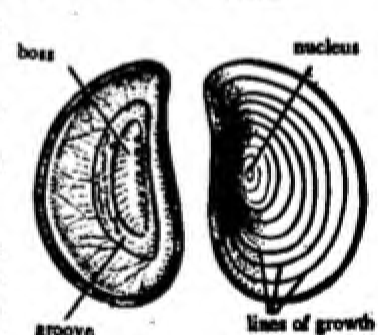


Fig. 62.3 *Pila*. Operculum A—Inner view, B—Outer view.

The shell is secreted by the *mantle*. The *periostracum* and the *ostracum* are secreted by the *supra-marginal groove* and the shell-gland respectively. The *hypostracum* is secreted by the general epithelial covering of the mantle, which also serves as an additional organ of respiration.

Mantle Cavity or Pallial Cavity. This is the large space whose roof and greater part of the sides are formed by the anterior

part of mantle and the floor and remaining part of the sides are formed by the dorsal surface of the body behind the head. In this cavity a number of organs are present known as *organs of pallial complex*. The organs of pallial complex are:

1. *Epitaenia*. When a longitudinal incision is given along the left of the ctenidium a prominent ridge, the epitaenia is seen on the floor of the mantle cavity. It arise near the right nuchal tube and extends up to the extreme posterior end of the cavity. It divides the mantle cavity into a small right *branchial chamber* and large left *pulmonary chamber*.
2. *Ctenidium or gill*. It lies at the extreme right side of the mantle cavity hanging vertically downwards from its dorso-lateral wall. Being monopectinate (come-like), its gill filaments or *lamellae*, which are somewhat triangular in shape, hang freely in the branchial chamber.
3. *Rectum*. It lies on the left of ctenidium on the floor of mantle cavity and opens to theexterior by anus, situated near the right *pseudepipodium* or right *nuchal lobe*.
4. *Genital duct*. The vas deferens in case of male or the oviduct in case of female lies in the brnchial chamber in between the rectum and epitaenia. Its opening is situated close to the anus. A hook-like *penis* can be seen in front of the genital pore in cse of male specimen. At the base of penis is found the *hypobranchial gland*.
5. *Hypobranchial gland* - It is a glandular thickening at the base of the penis. Its secretion helps in the act of copulation.
6. *Renal opening* - The anterior chamber of the renal organ projects into the branchial chamber as a small area of reddish colour, near the posterior temination of the epitaenia. Its external opening is like a transversely oblique slit situated in a shallow depression.
7. *The pulmonary chamber* - It is a sac hanging in the mantle cavity from the roof of mantle. It opens into the mantle cavity by the two rows of lamellae. It is *olfactory* in function.

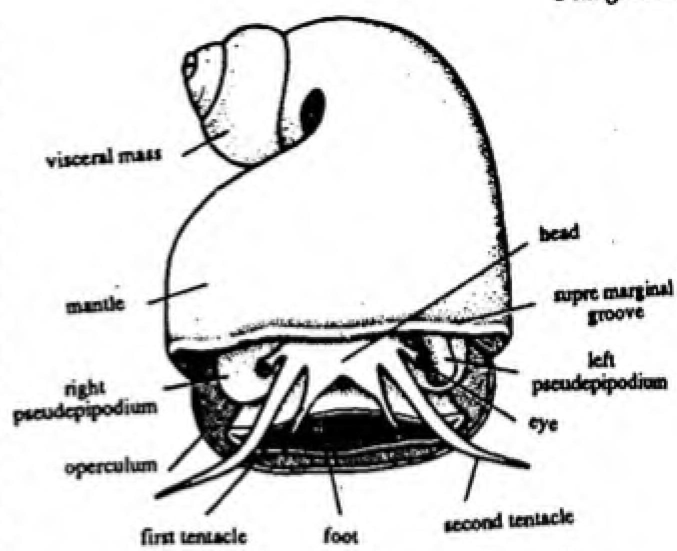


Fig. 62.4 *Pila*. Body after removing shell.

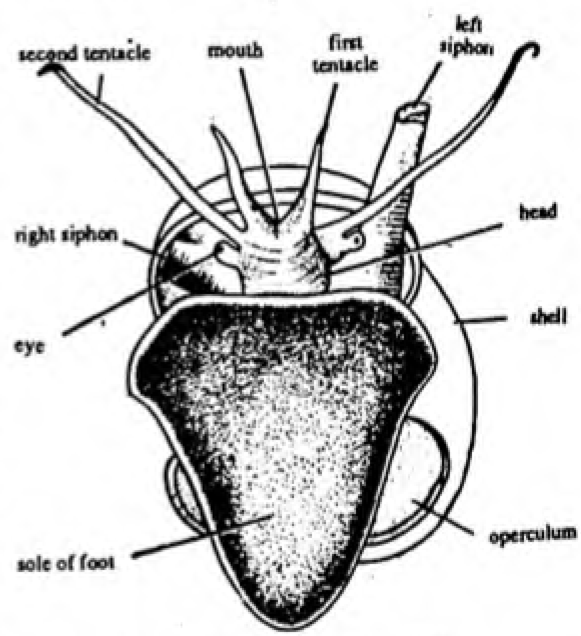


Fig. 62.5 *Pila*. Animal seen from the ventral side.

DIGESTIVE SYSTEM

The degestive system of *Pila* comprises:

I. Alimentary canal

II. Degestive glands.

I. Alimentary canal. The alimantary canal is tubular and peculiar due to the twisting of visceral mass. It is divisible into three parts, fore-gut,mid-gut and hind-gut.

1. Fore gut. It is also called stomodaeum and is ectodermal in origin. It is made up of buccal mass and the oesophagus.

Buccal mass. Mouth is a median vertical slit sityated at the tip of snout and is surroundedd by frilled folds of integument. True lips are absent. These frills serve as secondary lips. Mouth leads into the buccal cavity, which is the cavity of buccal mass. It is gratly obliterated and contains a pair of jaws and radula. The jaws divide the buccal cavity into two sections, the *anterior* also called *vestibule* and a *posterior*. The anterior chamber is extremely short. It posterior limit is marked by the presence of a pair of bands, which are especially thickened areas of the internal cuticular lining of the buccal cavity. In the posterior region

of buccal cavity there lien an *odontophore* or *tongue mass* on the floor of the buccal cavity. On the roof of buccal cavity occur the dorsal buccal glands.

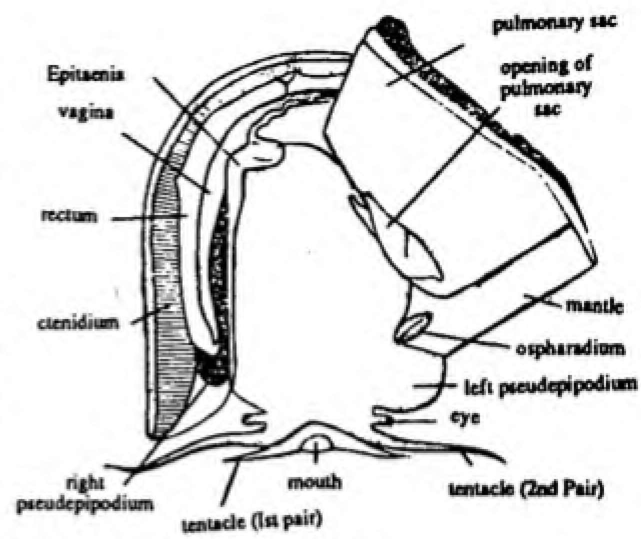


Fig. 62.6 *Pila*. Structure of mantle cavity.

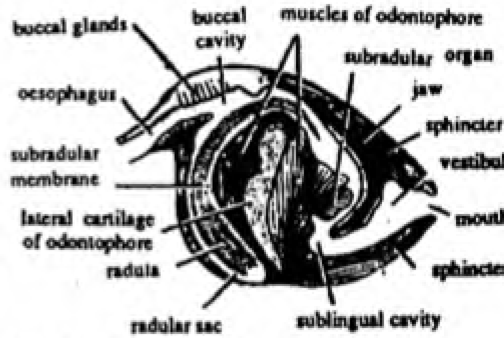
The odontophore is supported by *protractor* and *retractor* muscles and two pairs of cartilages. A pair of large S-shaped *lartal cartilages* and a pair of triangular *superior cartilages*. The cartilages project into the buccal cavity.

At the top of odontophore lies the radula, which is a star-shaped body and bears teeth on its upper surface which are arranged in transverse rows as in a file. Each transverse row of radula contains seven teeth including a large *central* or *median rachidian* tooth followed by one small lateral and two needle-like marginals on either side.

The teeth are made up of chitin reinforced by hardened protein. They bear sharp cutting edges meant for rasping vegetable. The old teeth are replaced by the new ones. The new teeth grow behind the radula and push it forward.

The number of radualr teeth in a row and the size and shape of teeth vary in different genera and species.

The two chitinous jaws form the posterior limit of the *vestibule*. The jaws lying dorsolaterally in the region of the sphincter muscle of the buccal mass are connected together by a cuticular membrane. The anterior cutting edge of each is *truncate* and *serrate* and bears two or three large teeth. Their movements are brought about by the sphincter muscles of the buccal mass. They appeaer to the formed by the simple local thickenings of the cuticular lining of these areas.



The buccal cavity lead into oesophegus.

Fig. 62.7 *Pila*. V.L.S. of buccal mass.

Oesophegus. It is like a long and narrowtube. It starts from the dorsal part of buccal mass and extends backwards along the median line to open into stomaach after the visceral mass. A pair of round coloured *oesophegeal pouches* are found in the lateral sides of oesophegus. Each pouh open at the junction of the oesophegus and the buccal cavity by means of a narrow duct. The pouches are the projections of oesophageal wall but their function is not well known. Probably they secrete digestive enzymes. They are also used to store food for some times.

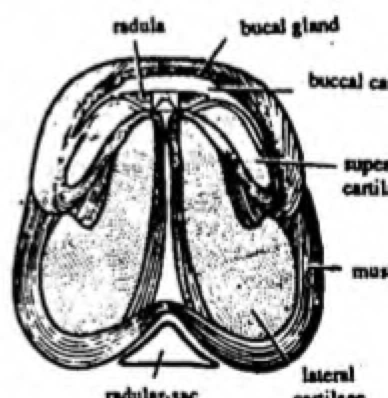


Fig. 62.8 *Pila*. Buccal mass in T.S.

2. *Midgut.* It comprises stomach and intestine. It is endodermal in origin.

Stomach. It lies on the left side of visceral mass, below the pericardium, embedded in digestive glands. Its internal cavity is U-shaped in appearence. The stomach contains two parts or chambers: the *cardiac* and *pyloric*. The cardiac chamber iis left or posterior part of stomach and forms its mainpart.It receives oesophagus. Its inner lining is thrown into longitudinal folds. The right or anterior limb of the stomach is *pyloric chamber* which is continued into the intestine. Its inner lining thrown into transverse folds. A blind pouch-like outgrowth the *caecum*, originates from the lower wall of pyloric stomach. It iis devoid of crystalline cone which has been observed in many other gastropods.

The digestive gland opens into the stomach by means of a duct at the junction of cardiac and pyloric stomach.

Intestine. The pyloric stomach followed by a narrow coiled tube, the *intestine*. In the begining the intestine runs bckwards,

then curves upward and takes 2 1/2or3 coils between the gonad infront and the digestive gland behind, before joining the rectum.

3. ***Hindgut.*** The hind-gut or proctodaeum is ectodermal in origin, comprising rectum.

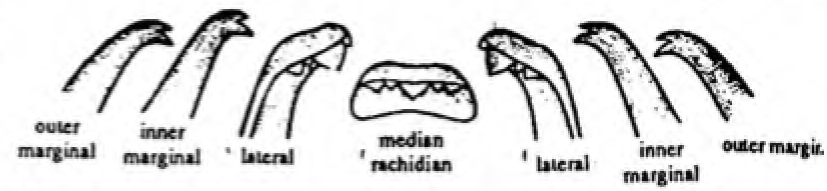


Fig. 62.9 *Pila.* Radula.

Rectum. It forms the tremninal part of alimentary canal. It is thick walled tube running into the branchial chamber and opens to exterior by the anus lying about 0.6 mm. from the edge of the right nuchal lobe.

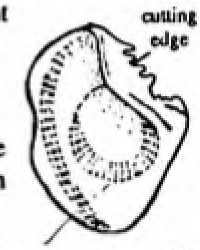


Fig. 62.10 *Pila.* A jaw

II. Digestive glands. A number of digestive glands are associated with alimentary canal. These are:

1. ***Salivary glands.*** Salivary glands are paired, white branching glands lying one on either side of the oesophagus behind the buccal mass. From each salivary gland a duct enters the *buccal mass* to open into it in the region of the dorsal buccal glands.

They secrete muscus and enzyme. Muscus helps in the lubrication of the radula and the smooth transport of food. The enzyme helps in digestion of starch.

2. ***Digestive gland.*** The digestive gland is large spirally coiled somewhat brownish or dirty-green in colour. It forms the greater part of the visceral mass. It consists or two lobes, the smaller is connected with the stomach, the bigger extends to apex of the spiral of the visceral mass. From each lobe arises a main duct, the two ducts unite to form a single duct before opening into the stomach. These ducts, into the digestive gland, branch repeatedly and end blindly ina very large number of small tubes, the *alveoli.* The alveoli are lined with a digestive epithelium made up of three types of cells- (i) *secretory cells* which secrete a cellulose digesting enzyme, (ii) *resorptive cells* which digest proteins intracellularly, and (iii) *lime cells* or *calciferous cells* which store calcium phosphate. Semi-digested food enters into these alveoli, where digestion of cellulose and proteins takes place.

This structure is regarded as *'liver* by most of the zooloogists but as it performs the functions of the various digestive glands and also is the main organ for the absorptioin of the digested food, therefore, *Dakin* has given the term *digestive gland* to this structure.

3. ***Buccal glands.*** A pair of elongated glands is present in the roof of buccal cavity. They secrete digestive enzymes.

4. ***Oesophegeal pouches.*** As already described, they probably secrete digestive enzymes.

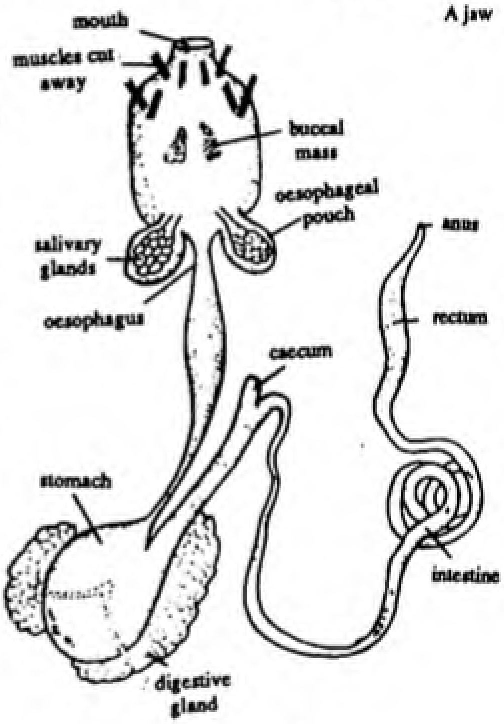


Fig. 62.11 *Pila.* Alimentary canal.

Food and feeding. The food consists cheifly of aquatic secculent vegetation. It is also reported that sometimes *Pila* feeds on dead animal tissues too.

By the contraction of the sphincter and protractor muscles of the buccal mass, the jaws move to the mouth and cut thin pieces of plants. Meanwhile, the *radula* is brought forward and the pieces of aquatic plants caught by its teeth are carried in to the cavity of the buccal mass as the radula moves backwards. The *chain saw* movement (described by *Huxley*) of the radula i.e., to-and for movement of the radula over the cartilage just lilke a band over the pulley is very characteristic. The movement of the *radula* is very much limited in Pila in comparison to other *gastropods.*

DIGESTION

The salivery glands pour their secretion into the buccal cavity where it mixes with the food. It converts insoluble starch into soluble sugar. In the stomach the food is digested by the secretion of the digestive gland. The digestive juice brings about the extracellular digestion of food, whereas intracellular digestion takes place inside the *resorptive cells* of digestive gland. The resorptive cell digest the cellulose portion of the food. Absorption of digested food takes place in the digestive gland and the intestine. The undigested food passes out from the rectum through the anus. From anus it comes into the branchial chamber and from there it comes to theexterior along with the out-going current of water.

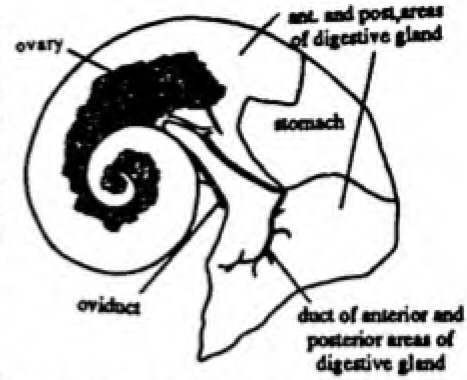


Fig. 62.12 *Pila.* Inner view of digestive gland.

RESPIRATORY SYSTEM

Pila is an amphibious animal so that it employes both aquatic and aerial methods of respirtion.

Organs of respiration. the organs of respiration consist of a pair of lefly expansions of mantle si uate in the pallial cavity and called *ctenidia, pulmonary sac* and a pair of *nuchal lobes.*

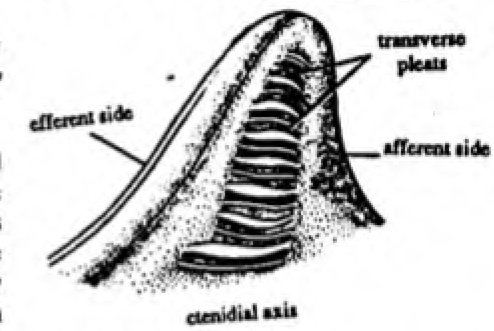


Fig. 62.13 *Pila.* A gill lamella.

1. *Ctenidia.* It consists of numerous thin *lamellae* attached to the mantle wall by their broad bases, but have their apices free in the branchial chamber. The line of attachment is known as *ctenidial axis.* A *ctenidium* with such an axis with a single row of lemmellae is described as *monopectinate gill* the lemellae present in the middle of the ctenidium are largest. They gradually become smaller towards the ends. Each lamella has a longer left side known as *efferent side* being on the side of efferent ctenidia sinus and the reltively smaller right or *afferent side* lying on the side of afferent ctenidial sinus.

Shallow transverse ridges, called pleats are found in the anterior and posteior regions of each lamellae.Each lamella arises as a double-layer of epithelium internally supported by connective tissue and muscle fibres. The epithelial layer consists of three kinds of cells.

(i) Non- ciliated columnar cells

(ii) Ciliated columnar cells

(iii) Glandular cells.

Underlying the epithelium there is a thin basement membrane below which lies connective tissue layer consisting of cells with a few scatted nuclei and large number of obliquely running muscle fibres. After the muscle fibres is situated a layer of pallial epithelium.

The ctenidium of *Pila* is situated on the right side of the body but the distribution of nerves in it and the position of ospharidium shows that gills of the left side has been pushed to the right side by extensive development of the pulmonary sac.

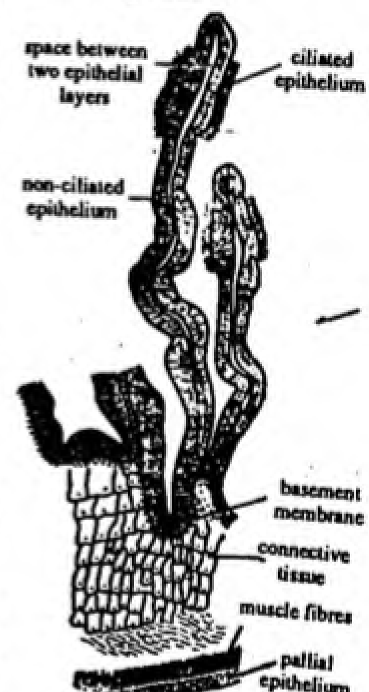


Fig. 62.14 *Pila.* T.S. of two gill lamella.

2. *Pulmonary Sac.* It is also known as lung. It is sac-like structure hanging from the roof of mantle cavity and is entirely closed except for a large opening with which it opens into the mantle cavity. It is developed from the mantle itself and consists of a densely pigmented deorsal wall and a creamy white ventral wall. The flaps on the two sides of the opening are of unequeal size, the left neing larger than the right and help in controlling the opening of pulmonary sac. The outer wall of the pulmonary sac consists of an external epithelial layer containing large numbers of fine black pigment granules. This is follow by a basement membrane below which lies a thick layer of connective tissue and finally the endothelium of the inner surface.

According to some workers the pulmonary sac is modified second ctenidium but this has not been proved to be correct.

3. *Nuchal lobes.* The mantle is provided with two fleshy and contractile *nuchal lobes* or pseuidopipodium on the two sides of head over the foot. The left nuchal lobe is well developed whereas the right is less developed. They form two respiratory tubular funnels longer and smaller during respiration.

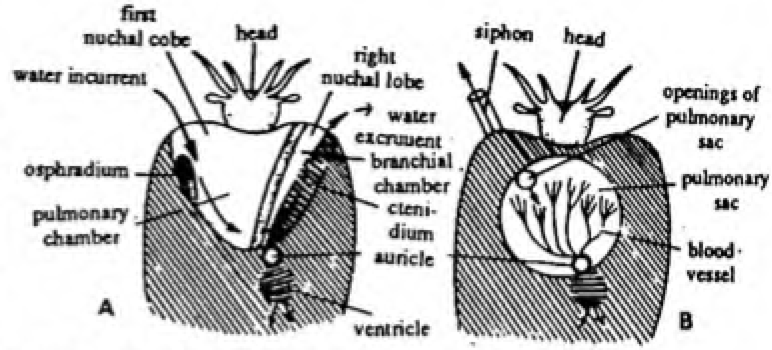


Fig. 62.15 *Pila.* Mechanism of respiration.

Mechanism of respiration

Aquatic respiration. Aquatic respiration usually takes place, when the animal lies submerged in the water, attached to the plants or floating in muddy water. During this process, the animal is fullly expanded, and the two nuchal lobes, which are equally expanded, appear more or less like shallow channels. The left *nuchal lobe* after a time increases in size and takes the form of a *gutter*. The respiratory current of water enters through the gutter-like *left nuchal lobe* flowing beneath the *osphradium* and reaches the posterior part of the *pulmonary chamber* of the mantle cavity and then corssing the *epitaenia* it enters the branchial chamber, where it bathes the entire length of the gill allowing exchange of gases and, finally, passes outside through the *right nuchal lobe.*

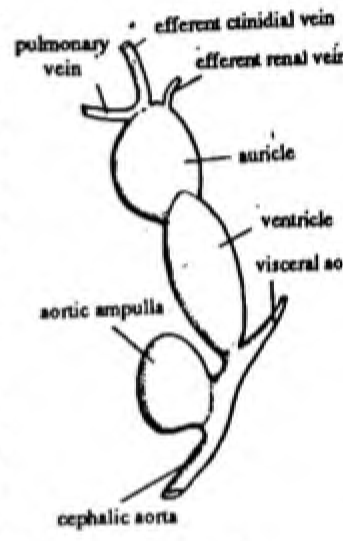


Fig. 62.16 *Pila.* Heart.

Aerial or pulmonary respiration. The aerial respiration ocurs either when the pond water is poor in Oxygen or *Pila* is making excursion on land.

Pila moves towards the surface of water and thrusts out its left nuchal lobe which becomes elongated and tubular to form the resppiratory siphon. The pulmonary chamber becomes greatly enlarged and is completely cut off from the branchial chamber. The air enters the pulmonary sac through respiratory siphon and the respiratory movements produced by the altermate contraction and expansion of the pulmonary sac help in inspiration.

While *Pila* is on land, the respiratory siphon is not formed and the air enters pulmonary chamber directly through the expanded nuchal lobe.

Blood vascular System

The blood vascular system is highly developed due to its amphibious nature. It consists of:

(I) heart

(II) blood vessels

(III) blood.

I. Heart. It is two chambered consists of an auricle and a ventricle and lies enclosed in *pericardium.*

(i) *Pericardium.* The pericardium is thin walled, oval chamber enclosing the heart and situated between the pulmonary chamber and the posterior renal sac on the left side of the body whorl. Posteriorly, it is surrounded by the stomach and the digestive gland. The renal sacs are present on its dorsal side while the oesophagus is found on its ventral side. The pericardial cavity is the true coelom as it communicsates with renal organs and the reproductive organ develops from its wall in early stages of development. Pericardium communicates with the posterior renal chamber by *reno-pericardial aperture.*

(ii) *Auricle.* The auricle is a thin walled, roughly triangular sac highly contractile in nature. It is situated on the dorsal side

of pericardium. It receives blood through three main veins- (a) *efferent ctenidial vein* (b) *efferent renal vein* and (c) *pulmonary vein.* At the lower end it is connected with ventricle through the *auriculo-ventricular aperture.* The aperture is guarded by two semilunar valves which allow the blood to flow from auiricle to ventricle but not in reverse direction.

(iii) *Ventricle.* It is an ovoid sac lying below the auricle. It has thick, spongy and muscular walls and a reduced cavity due to a coarse meshwork of muscular strands. From the lower end of the ventricle arises a large artery, the *aortic trunk.* The opening between the ventricle and aorta is guarded by two semi-lunar valves which prevent the flow of blood back into the ventricle.

II. Blood Vessels. It inclundes arteries, sinuses and veins.

1. Arteries. The aortic trunk divides immediately into two branches an anterior *cephalic aorta* and a posterior *viseral aorta.*

(a) *Cephalic aorta.* There is a thick-walled *ampulla* at the base of the cephalic aorta. It is highly elastic and helps in pumping the blood. The cephelic aorta, beyond the ampulla, gives off immediately three arteries on the outer side.

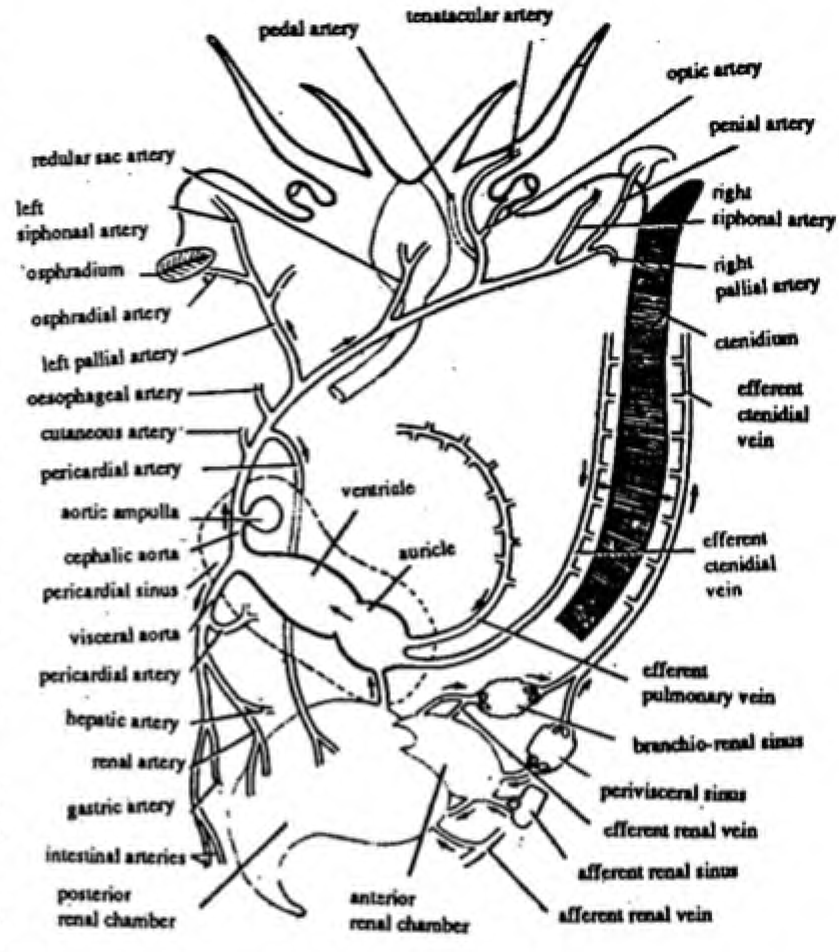


Fig. 62.17 *Pila.* Heart and blood vessels.

(i) A *cutaneous artery* which supplies the skin.

(ii) A pair of *oesophageal arteries* which supply the oesophagus.

(iii) A thick *pallial artery* which supplies the left side of mantle, left nuchal lobe and osphradium.

(iv) A *pericardial artery* arises from the inner side of the cephalic aorta. It supplieds blood to the pericardium.

The main aortic trunk after giving off above branches, reaches the proterior renal chamber and supplies both the renal chambers by many branches, the *renal arteries.*

The main branch of the cephelic aorta now runs along the left side of the oesophegus for a short distance and then corsses over to its right. Here it appears as a large artery and gives off a number of small branches to the oesophagus and the floor of mantle cavity. On its rightside it divides into three branches.

(i) *Right pallial artery* to the right side of the mantle.

(ii) *The riglu siphonal artery* to the right nuchal lobe.

(iii) *The penial artery* to the copulatory organs.

The main cephalic aorta again divides into following four branches:

(i) A *redular sac artery* to the redular sac.

(ii) A pair of *optic nerves* to the eyes.

(iii) A pair of *tentacular arteries* to the tentacles.

(iv) *Pedal arteries* which branches to form a network in foot.

(b) *Visceral aorta.* It passess thorugh the visceral mass and supplies blood to the visceral organs by the following branches:

(i) A *pericardial branch*, which supplies the pericardium, the anterior part of the digestive gland and the skin.

(ii) A large *gastric branch*, which supplies the different parts of the stomach.

(iii) A number of small *intestinal arteries*, which supply the intestine.

(iv) A large *digestive branch*,which supplies the digestive gland and the gonad.

(v) Many *renal arteries* to the anterior and posteior renal chambers.

In the end the visceral aorta terminate into branches which supply the rectum and anus.

2. ***Sinuses.*** The ultimate branches of the arteries open into wide spacews without walls, called the *blood sinuses*. Some of them act as blood capillaries and contact the arteries with the veins. Other sinuses join together to form larger sinuses. In *Pila* there are four sinsuses:

(i) *Perivisceral sinus.* It occupies the anterior part of the body above the foot and below the floor of mantle cavity. It surrounds the anterior part of alimentary canal.

(ii) *Peri-intestinal sinus.* The peri-intestinal sinus is confined around the coils of the intestine.

(iii) *Branchio-renal sinus.* It lies along the right side of the anterior renal chamber.

(iv) *Pulmonary sinus.* It is confined to the walls of the pulmonary sac.

3. ***Veins.*** The veins carry the venous blood from the various part of the body to the auricle directly or through the respiratory and excretory organs.

(i) *Afferent ctenidial vein.* It collects blood from the perivisceral sinus, branchio-renal sinus, rectum and the terminal part of the genital duct and carries it to the ctenidium, where it branches to supply blood to the branchial lam*ellae for purification.*

(ii) *Efferent ctenidial vein.* It collects oxygenated blood from the lamellae of ctenidium, mantle and copulatory organ and carries to the auricle.

(iii) *Afferent renal vein.* It receives blood from the peri-intestinal sinus and empties into the posterior renal chamber.

(iv) *Efferent renal vein.* It orginates from the posterior renal chamber and empties in to the auricle.

(v) *The pulmonary vein.* It collects blood from the pulmonary sac and carries it to the auricle.

III. Blood. The blood is colourless and contains colourless amoebocytes in the plasma. The blood of *Pila* has a light bluish tinge. A respiratory pigment, the haemocyanin is found dissolved in the plasma. The haemocyanin helps in respiration.

Course of Circulation.

The ventricle pumps the mixed blood through branches of cephalic aorta and visceral aorta to various parts of the body. The venous blood is collected from the various parts into the perivisceral and periintestinal sinuses. From these sinuses the blood is sent back to the auricle either directly through kidneys for the removal of nitrogenous waste products or indirectly to the gill and mantle dudring aquatic respiration. The auricle thus gets aerated and non-areated blood from these organs and it is the mixed blood which is forced into the ventricle to be pumped again to various organs of the body.

EXCRETORY SYSTEM

In *Pila globosa*, there is a single large *renal organ* or *kidney* or *organ of Bojanus* lying behind the pericardium. The excretion

is done by the left-kidney as the right kidney has modified into the gonoduct. On one side it opens into the pericardial cavity and on the other to the outside through the mantle cavity.

The renal organ is made up of two distinct parts: a right *anterior renal chamber* and a left *posterior renal chamber.*

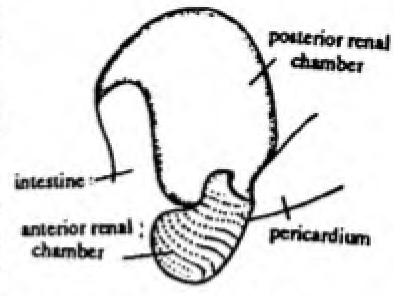


Fig. 62.18 *Pila.* Renal Chamber

1. **Anterior renal chamber.** It is oval, reddish organ, lying on the dorsal side of the animal infront of the *pericaridum* and *posterior renal chamber.* The cavity of the anterior renal chamber is very small due to the presence of a number of triangular leaf-like processes or *lamellae* are arranged on either side along a thick median longitudianl axis, or the *efferent renal sinus.* On the floor of the chamber, the *lamellae* are arranged on either side of a median axis, the *afferent renal sinus.* The anterior renal chamber communicates with the posterior renal chamber through a small opening at one end and opens by an elongated opening into the mantle cavity lying to the right of the *epitaenia,* at the other end.

2. **Posterior renal chamber.** It is hook-like broad chamber brown or grey in colour situated behind the anterior renal chamber, in between the rectum on the right and the pericardium and the digestive gland on the left. Its large internal cavity encloses a part of the genital duct and a few coils of thje intestine. At one end, it communicates with the anterior renal chamber through an aperture and at the other with the pericardium through an elongated slit-like reno-pericardial aperture, perforating a thin vertical reno-pericrdial septum, separating the two. The afferent and efferent renal vessels profusely branch in the roof of this chamber.

Physiology of excretion. The renal organ separates the nitrogenous waste from the blood. The excretory fluid passes from the posterior renal chamber to the anterior renal chamber from where it is discharged into the mantle cavity through the external renal aperute and finally it goes out with the outgoing current of water through right siphon. The excretory matter ocontains chiefly ammonia compounds, urea and uric acid. For conserving water, *Pila* converts ammonia into insoluble uric acid.

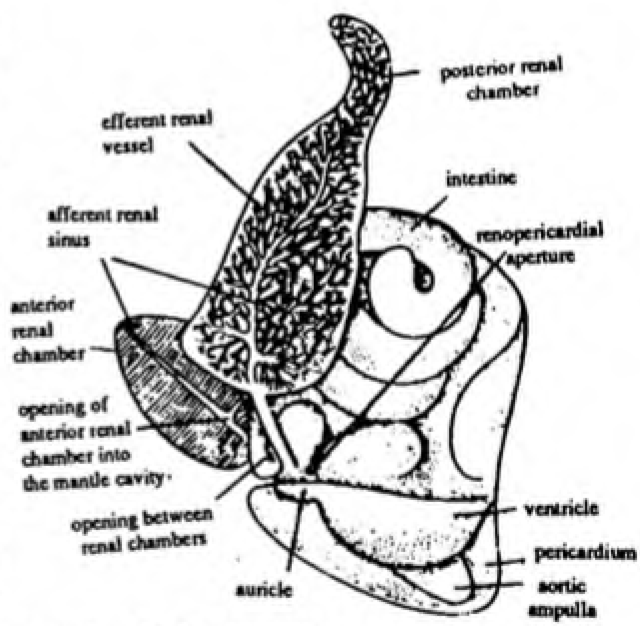


Fig. 62.19 *Pila.* Excretory system.

In most of the gastropods, the digestive gland also forms and organ of excretion. These are eleminated by way of stomach and intestine.

NERVOUS SYSTEM

A well-developed nervous system. it possess two characteristics (i) except the visceral ganglia all other ganglia form a ring-like structure around the buccal mass (ii) due to torsion the visceral loop is twisted to form the shape of '8'. The nervous system of *Pila* includes the following ganglia, their commissures and connectives:

1. **One pair of cerebral ganglia.**
2. **One pair of buccal ganglia.**
3. **Paired pleuro-pedal ganglionic mass.**
4. **One pair of visceral ganglia.**

5. Unpaired supra-intestinal ganglion.

1. **Cerebral ganglia.** A pair of large, flat and conical cerebral ganglia are situated on the dorso-lateral sides of buccal mass. These are connected together by thick, band-like *cerebral commissure* dorsally. In addition to this both these ganglia are also connected with each other by thin *labial commissure* lying below the cerebral commissuse.

Each cerebral ganglion is connected with the *buccal ganglia* of its side by *cerebro-buccal connective* and by *pedal and pleural* ganglia by a thick band-like *cerebro-pedal* and *cerebro-pleural connectives.* All these connectives are situated on the lateral sides of buccal mass.

Anteriorly the cerebral ganglia give nerves to the skin of snout, tentacles and buccal mass. Posteriorly, they give nerves to tentacles, eyes and the statocyst.

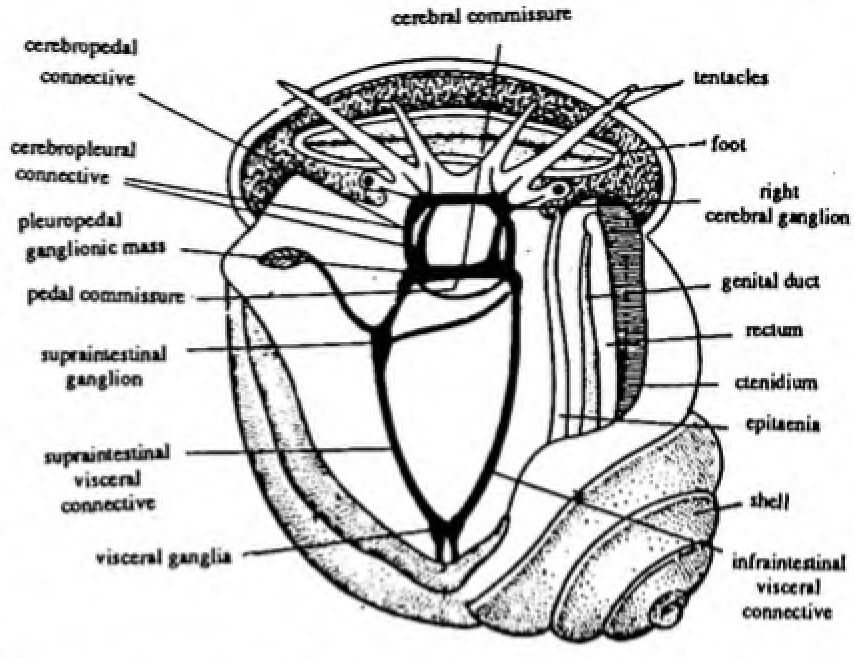


Fig. 62.20 *Pila.* Nervous system.

2. **Buccal ganglia.** They are two in number. They are situated on the dorso-lateral sides of the buccal mass at its junction with the oesophagus.The two buccal ganglia are connected with each other by a stout buccal commissure, which runs on the ventral side of the oesophagus behind the buccal mass. Each ganglion is also connected with the cerebral ganglion of its side by the cerebro-buccal connective.

The nerves are supplied from each buccal ganglion to the posterior part of *buccal mass* and *radular sac.*

3. **Pleuro-pedal ganglia.** A pair of large, somewhat triangular ganglionic masses present one on either ventro-lateral side of the buccal mass. Each one is formed by the fusion of an outer *pleural* and an inner *pedal* ganglion, separated by a faint notch. The right pleuropedal ganglionic mass also consists of the *infra-intestinal ganglion* fused with it.

The two pedal ganglia are connected with each other by two *pedal commissures* which are placed one above the other. These commissures are situated below the buccal mass. Many nerves are given off to the foot from the anterior and posterior parts of the pedal ganglion. Behind the pedal commissures, the two pleural ganglia are connected with each other by *infra intestinal nerve.*The left pleural ganglion gives off nerves to the m,antle, osphrodium, left nuchal lobe, columellar muscles and the anterior part of gill. The right pleural ganglion supplies nerves to parietal wall, epitaenia, right nuchal lobe, copulatory organs, rectum, genital duct and columellar muscles.

4. **Supra-intestinal ganglion.** It is a fusiform ganglion situated on the left side 1/4th of an inch away form the pleuro-pedal mass of its side. It is connected anteriorly to the left pleural ganglion, posteriorly to the left visceral ganglion by thick nerves and on its inner side to the *sub-intestinal ganglion* of right side by a thin nerve. The thin nerve is known as *supra-intestinal nerve.* On its outer side the supra-intestinal nerve issues a short but thick nerve to the mantle and the anterior part of the ctenidium.

5. **The visceral ganglion.** It is formed by the fusion of two spindle-shaped ganglia. It lies at the base of the visceral mass. It is connected with the *right pleural ganglion* by a thin nerve, the *infra-intestinal visceral connective* and with supra-intestinal ganglion by the left supra-intesinal visceral connective. It supplies nerves to the renal organ, genital organ and ot the stomach and digestive gland.

SENSE ORGANS

The entire exposed surface of *Pila* is provided with sensory cells but followings are special sensory organs:

1. **Ospheridium.** A small osphreidium is present in aquatic gastropods while absent in terrestrial snails. It was specially described by *Spengel* (1881), *Bernard* (1890), *Demal* (1954). It is unpaired in *Pila* and situated dorsoventrally on the roof of mantle cavity. It is bipectinate structure hanging like a curtain in the course of the respiratory water current. It consists of a specialized and usually elevated and ciliated region of the epithelium in which there is an accumulation of the sensory cells. The leaves of ospheridium are arranged on both the sides of a centrl axis. Each leaf is just like a double fold of the wall of central axis.

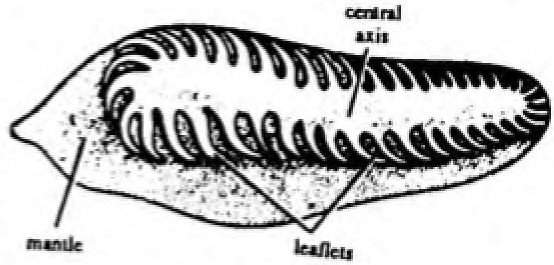


Fig. 62.21 *Pila.* Ospherifium.

In a transverse section, the oshradium consists of an outermost covering of a single layered *epithelium*, internally lined by a thin *basement membrane*, the interior filled up with *nerves*, *connective tissue* and *blood spaces*. The epithelial cells are elongated possessing basal nuclei, and they are of three types- (i) *sensory*, (ii) *ciliated* and (iii) *glandular*. The ciliated cells line the attached margin, while the sensory cells devoid of cilia cover the osphradium. The flask-shaped glandular cells are found scattered among the sensory cells.

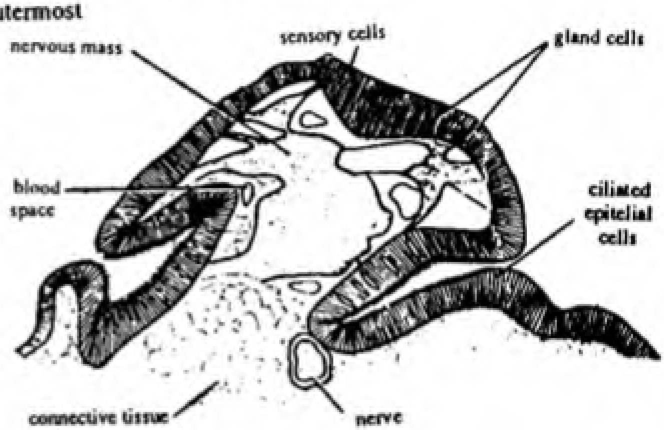


Fig. 62.22 *Pila.* T.S. of Ospheridium.

Formerly it was regarded as a rudimentary gill, but it has now been established that the ospheridium serves to test the chemical and physical properties of water. The osphredium helps in the selection of food material (*Spengel*).

2. **Eyes.** Two eyes are borne on short stalks called *ommatophores* situated behind the second pair of tentacles.

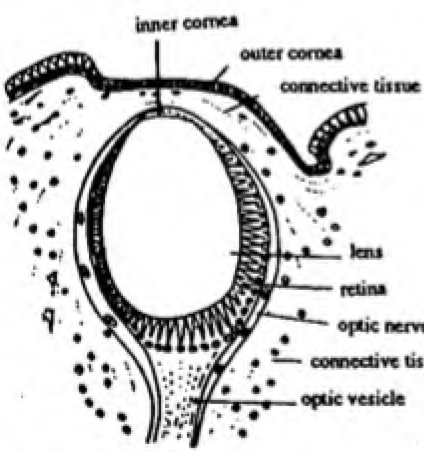


Fig. 62.23 *Pila.* H.L.S. of eye.

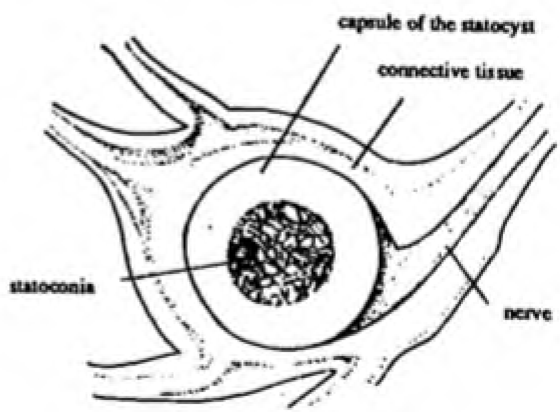


Fig. 62.24 *Pila.* Statocyst.

In section the eye is in the form of a pyriform cup or optic vesicle. The outer epithelium of the eye-stalk continues over the eye forming the *cornea or pellucid externa*. It consists of a row of squarish cells devoid of pigments. Lying below the cornea is thick layer of connective tissue made up of fibres and nuclei. This layer encloses the pyriform *optic vesicles* consisting of a transparent epithelium forming *inner cornea or pellucida interna* lying next to connective tissue. The ovoidal structureless *lens* occupies the central space of the vesicle. The sensitive part of the eye of the *retina* forms the outer coat of the vesicle made up of large cells filled with pigment granules. Retina consists of large pigmented cells, which are of two types: (1) largbe, broad cells with hair-like processes on their outer ends, the *visual cells* and (2) the compress cells lying in between the visual cells, the *supporting or packing cells*. Both kinds of cells at the inner ends are connected with nerve-cells and branches of optic nerve, which enter the optic vesicle at its posterior

end. Internally, the retina is bounded by a basement membrane.

The eyes of *Pila* do not play an important role for sight. The snail seems to be unable to distinguish objects but only responds to the changes in the intensity of light and can detect quick movements.

3. **Statocysts.** The statocysts are two pyriform sacs of creamy white colour lying posterior to the pedal ganglion of each side and are not innervated from these ganglia. These are connected to cerebral ganglia by a pair of slender statocyst nerves. The statocyst is filled with fluid and contains a single large *statolith* or few to many smaller bodies called *statoconia* floating in the fluid. Formarly it was supposed to be the organ of hearing and hence it was called *otocyst* but it is proved that these are the organs of equilibrium (*Delage*).
4. **Tentacles.** There are two pairs of cephalic tentcles in *Pila*. The second pair of tentacles are *rhinophore or olfactory organs.*

REPRODUCTIVE SYSTEM

Pila is unisexual a well marked sexual dimorphism is seen. The shell of male is smaller than that of female. In male penis is well developed and the female has a more swollen body whorl than the male.

Male Reproductive System. The male reproductive orgns comprises:

1. Testis
2. Vasa efferentia
3. Vas deferens
4. Seminal vesicle
5. Penis
6. Hypobranchial gland.

1. *Testis.* It is a single, flat, plate-like and roughly triangular whitish structure, occupying the upper part of the first two or three whorls of the shell. It lies in close association with the brownish or greenish digestive gland along its upper and inner or columellar sides and appears quite distinct on account of its creamy colour. A thin cutaneous membrane separates the testis from the shell.

The germinal epithelium of testis produces two types of sperms:

(i) *Eupyrene sperms.* These are small and thread-like. Their body consists of a head and a tail. These are motile and fertilize the ora. They measure 25 μ long.

(ii) *Oligopyrene sperms.* They are large semi-circular or spindle-shaped. The head is large and the tail bears 4 or 5 cilia. These are non-motile and incapable of fertilizing ova.

2. *Vasa efferentia.* From the testis arise several delicate ducts called vasa efferentia. They unite towards the posterior edge of testis to form a common duct, the *vas deferens.*
3. *Vas deferens.* The vas deferens commences

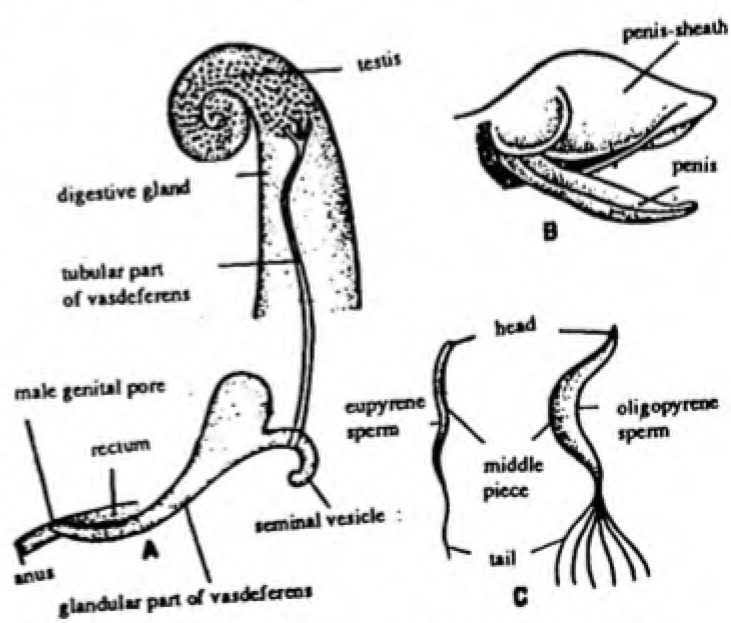


Fig. 62.25 *Pila.* A—Male reproductive organs, B—Copulatory organ, C—Sperms.

from the posterior part of the testis and passes under the skin and is differentiated into two parts:

(i) *Proximal tubulr part.* It forms posterior part of testis under the skin along inner side of the digestive gland upto the posterior renal chamber and finally turns towards the left to approach the pericardium. Here it opens into the terminal glandular part of the vas deferenss.

(ii) *Terminal glandular part.* It is the distal thick-walled glandular part of the vas deferens which runs along the left side of the rectum into the branchial chamber and opens into it by male genital pore. The male genital pore is situated a little behind the anus to a claw-like projection of *genital papilla.*

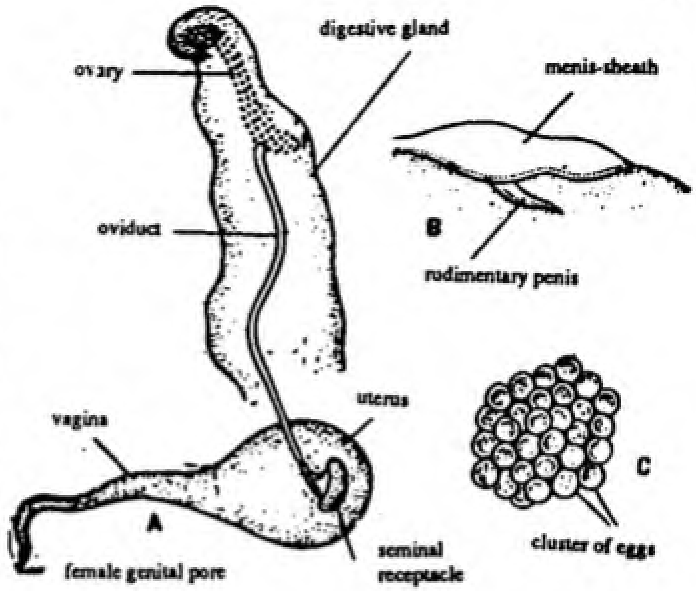


Fig. 62.26 *Pila.* A—Female reproductive system, B—rudimentary organ, C—eggs.

4. ***Seminal vesicle.*** It is situated on the right of the pericardium at the junction of the anterior and posterior renal chamber. It is swollen flask-shaped structure whose distal end is closed. The seminal vesicle stores the sperms and opens into the vas deferens at the junction of its tubular and glandular parts.

5. ***Penis or Copulatory organs.*** On the left side of the inner surface of the mantle, there is a thick glandular flap of yellowish colour. It is attached along its right side but its left free edge is rolled to form spout-like penis-sheath. Inside the sheath is the penis.

The penis is about 1.25 cm. long, provided with flagella arising from the roof of the mantle. It is slightly covered with swollen base and tapering end has a groove along its length on the inner side. It is capable of great extension.

6. ***Hypobranchial gland.*** It is a glandular structure with pleated surface at the base of penis-sheath. The gland is without duct and, therefore, its secretions are poured directly upon its surface.

Female Reproductive Organs. The female reproductive organs are following:

1. Ovary
2. Oviduct
3. Seminal recepticle
4. Uterus
5. Vagina
6. Copulatory organ
7. Hypobranchial gland.

1. *Ovary.* The ovary is present in the same position as the testis in the male. It is found in two or three whorls of the shell. It is orange coloured structure remains attached to the inner surface of the digestive gland. Branches of the ovary are single layered, flask-shaped structures with slender tubular necks uniting together to form minute ducts which open into oviduct.

2. *Oviduct.* The oviduct is a semi-transparent, narrow tube arising from the middle of the ovary and passing downwards along the margin of the digestive gland. Finally, it ascends upwards to receive the opening of receptaculum seminis.

3. ***Seminal recepticle.*** The small, bean-shaped *receptaculum seminis* or seminal receptacle lies enclosed within the cavity of

the posterior renal chamber, closely attached ventrally to a thin-walled pouch from the walls of the uterus, called the *pouch of the receptaculum*. It is meant for storing the sperms received from the male *Pila* during copulation.

4. *Uterus*. It is a large, yellow and pear-shaped structure situated below the intestine in the body whorl. It is differentiated into a broad rounded *basal part* and a narrow tubular *apical part*. Seminal recepticle opens into the basal part while apical part receives the vagin.

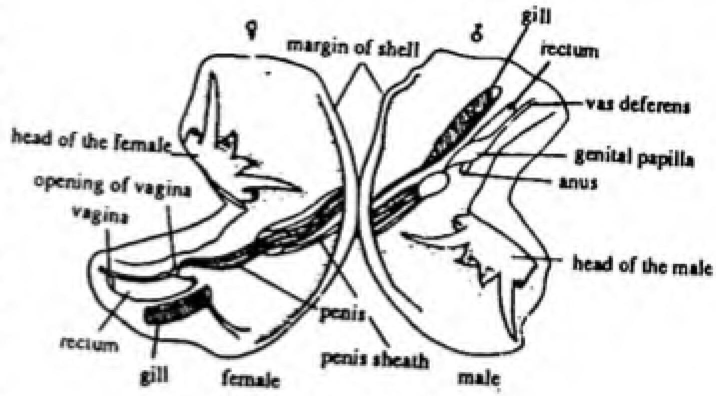


Fig. 62.27 *Pila*. Showing Copulation.

5. *Vagina*. The terminal narrow part of the oviduct is known as vagina. It is a cream-coloured tube which runs forward on the right side of rectum to open into the branchial chamber by *female genitl aperture* situated behind the anus.

6. *Copulatory Organ*. The rudimentary penis is not enclosed within a well-developed *penis-sheath*, but lies beneath a glandular fold of the mantle. It is a thin, flageller structure nearly 6mm. long and uniform in thickness but pointed at the tip. It also bears a rudimentary groove along its inner surface, like the penis of the male.

7. *Hypobranchial gland*. It also represents the rudiment of the hypobranchial gland of mle as an incipient glandular thickening.

Copulation. Snails breed during rainy season. Copulation takes place in the water of ponds or on their banks and continues for 3 hours or more. The penis becomes connected at the base with genital papilla at the end of the terminal part of vas deferens and along the sheath is inserted into the mantle cavity of the female snail. the tip of the penis enters the vaginal opening, and through this connection the spermatic fluid is transferred to be seminal recepticle of the female.

Fertilization. Fertilization is internal but the development of the embryo takes place outside the body of female. Ovulation takes place two days after copulation. Female lays 200-280 eggs at a time in moist earth in a sheltered cavity near ponds and lakes.

Development. The eggs are rounded and as big as the pea-seeds. Each egg consists of an outer whitish shell, enclosing a double shell membrane, a thick mass of solid white albumen and a little central mass of liquid albumen containing the embryo. During development the visceral mass and the shell of embryo become spirally coiled and a characteristic phenomenon of *torsion* takes place resulting in the asymmetry of the body. The young snails emerging from the eggs are similar to the adults.

63

UNIO

Unio comes under class Pelecypoda or Bivalvia in which an external and internal symmetry is seen unlike gastropods. The cephalic region is rudimentary and the body is laterally compressed.

SYSTEMATIC POSITION

Phylum	-	Mollusca
Class	-	Pelecypoda
Order	-	Eulamellibranchiata
Genus	-	*Unio* or Anodonta

DISTRIBUTION

The 'freshwater mussel' is a familiar representative of phylum Mollusca. The family Unionidae to which *Unio* belongs is cosmopolitan in distribution. The family comprises several genera and about 1000 species of which a good number are represented in India. *Anodonta* is the common representative of Britain, while in India *Unio* and *Lamellidents marginalis* are of common occurance.

HABITS AND HABITATS

It is found in rivers, streams, lakes and ponds. During day time it usually lives partly burried in mud or sand at the bottom, keeping its posterior end exposed. It comes out to shallow places in night. They may also occur wedged in between the rocks and stones, with the valves slightly spread and the two siphons exposed. It slowly creeps with a ploughshare-like muscular foot. It hardly covers 16 kilometres in a year. Sexes are separate but there is no sexual dimorphism externally. Development is indirect through a larval stage and takes place in brood chamber, which are enlarged water tubes of female's gills.

EXTERNAL FEATURES

Shape and size. It is laterally compressed. It is elongated and enclosed and protected in a bivalve shell. The size varies from 2" to 4" in length.

Shell

A typical bivalve shell consists of two similar more or less oval usually convex valves which are attached and articulate dorsally with each other. Each valve bears a dorsal protuberance called the umbo which rises above the line of articulation. The umbo is the oldest part of the shell, and the concentric lines around it are lines of shell growth. The two valves are attached by an elastic protein band called the *hinge ligament*, which is covered above with the *periotracum*. The hinge ligament is so constructed that when the valves are closed, the dorsal part is stratched and the ventral or inner part is compressed. Thus, when adductor muscles

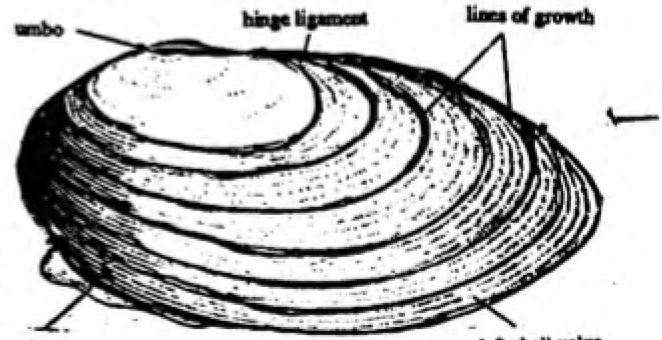


Fig. 63.1 *Unio*. External feature.

relax, the ligament causes the valves to open. The inner surface of each valve possesses dorsally along the hinge line, small sharp ridges and teeth-like projections separated by groove or sockets. These are called *hinge teeth.* The teeth of one valve fit into the corresponding sockets of the other to prevent lateral slipping. However, a dorsal fold of mantle tissue still lies between the tooth and socket of two opposing valves.

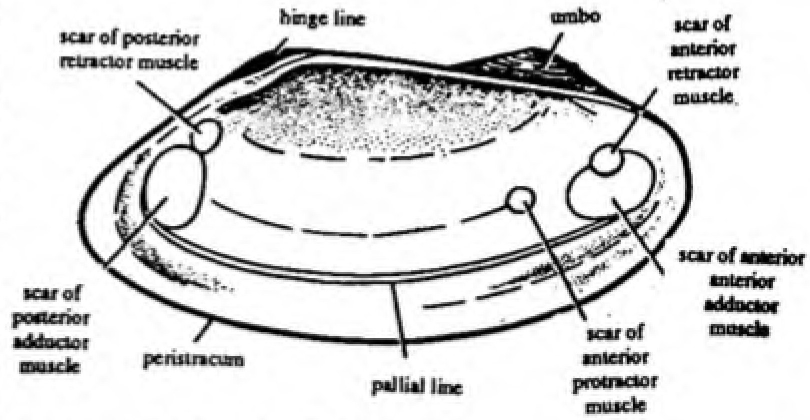


Fig. 63.2 *Unio*. Inner view of left shell.

The valves of the shell are pulled together by two large dorsal muscles, called *adductors.* The posterior muscle being larger than that of the anterior. Near the impression of the anterior adductor muscles are two small impressions, the dorsal and posterior one left by anterior retractor muscle and a ventral and posterior by protractor muscle. A small impression of a posterior retractor muscle also lies dorsal to the impression of posterior abductor muscle.

Running parallel to the ventral margin of the valves from one adductor impression to the other is a thick line known as *pallalial line*, which is caused due to the insertion of muscle fibres from the edges of the mantle.

Microscopic structure of shell: The shell consists of three distinct layers:

1. *Priostracum.* It is the outermost thin trnslucent and greenish brown layer formed of a special chitinous substance, the *conchiolin.* The colour of the shell is due to this layer. It is secreted by the edge of the mantle and is a protective layer for the underlying calcareous prismatic layer which otherwise can be eroded out by the action of carbolic acid of the surrounding medium. The periostracum is worn away from the older part of the shell, like umbo, leaving the prismatic layer exposed to the exterior.

2. *Prismatic layer.* It is the middle layer and is crystelline. It is made up of calcium carbonate separated by thin layers of conchiolin. It is arranged perpendicularly to the surface of shell. It is also secreted from the edge of mantle.

3. *Nacreous layer or pearly layer.* It is the innermost layer of shell also known as the *mother of pearl* or *nacre,* since it presents a smooth, iridescent surface. It is secreted by the whole outer surface of mantle and is in the form of alternative transverse layers of $CaCO^3$ and conchiolin. The layer of both the types run parallel to the shell surface.

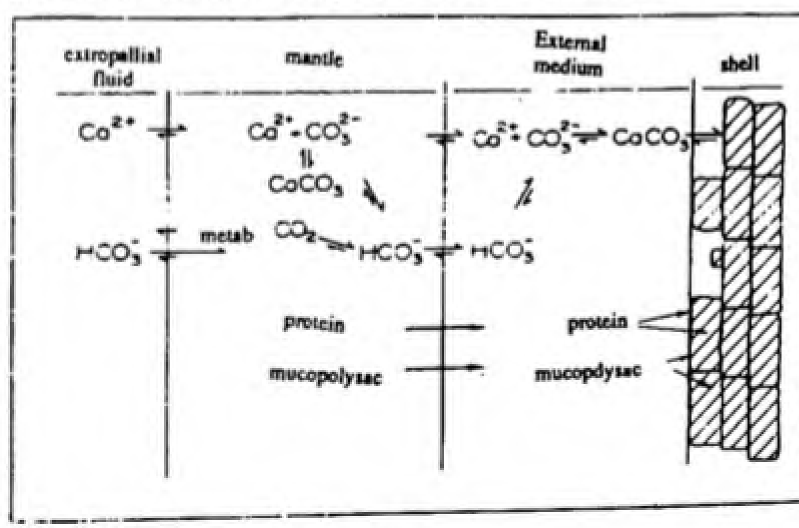


Fig. 63.3 *Unio*. Process of shell secretion.

Formation of shell

The shell is made up of calcium carbonate (89-99%), very little of phosphate of lime (1-2%) and organic base called the conchiolin. Two theories have been proposed regarding the formation of shell.

1. *Bowerbank and Carpenter's Theory.* According to *Bowerbank* and Carpenter, the shell is formed by the growth of interstitial deposits like that of formation of teeth and bones in higher vertebrates.

2. *Reaumur - Eisioz Theory.* According to this thoery the shall is formed by the cuticle-like deposition on the outside of skin. It is formed by minute calcareous particles which bounds together. Mantle takes important part in the deposition of shell. Every portion mantle bears shell deposition cells. These cells separate the carbonate of lime from blood, which is the main constituent of shell. The umbo portion of shell is secreted first and subsequent layers are added in gradual succession forming the lines of growth.

The edge of the mantle bears three folds an inner, middle and outer. The outer fold is related to secretion of the shell. The inner surface of outer fold lays down the periostracum and the outer surface secretes the first calecareous layer. The entire mantle surface secretes the remaining calcareous cells.

Mantle

When the shell is removed, the soft body of the animal is exposed, covered in a thin, semi-transparent soft fold of skin, called *mantle* or *pallium*. It consists of two lateral halves or mantle lobes or folds, which correspond to the two valves of the shell. These lobes are thin sheets of tissues closely attached to the inner surface of the valve. The lobes come off from the dorsal part of the body-wall, while, ventrally and anteriorly, they are free, posteriorly, they are fused in the middle to from a dorsal and a ventral *siphon*. These siphons allow water in and out. Currents of water enter through the *ventral* or *incurrent* or *inhalant siphon*. The ventral siphon is formed by approximation of mantle lobes and its edge are provided with small tentacles. The water leaves through the dorsal or excurrent or exhalant siphon. On the posterio dorsal side, the two mantle lobes also form a dorsal - mantle pore. Histologically, the mantle consists of:

1. An outer layer of columnar epithelium beset with numerous unicellular glands secreting **nacre**.

2. A middle fibrous connective tissue.

3. An inner ciliated epithelium containing mucous secreting cells.

Mantle cavity or Pallial cavity

The space enclosed between the two lobes of mantle is called **mantle cavity**. It encloses viseral mass, gills, foot etc. which are exposed when one fold is removed.

(i) *Visceral mass.* It occupies the dorsal part of the mantle cavity. It is dark in colour and contains various organs such as digestive system, circulatory system, excretory system and reproductive system. A greenish-brown digestive gland is present in the anterio-dorsal region. A pericardial cavity containing the heart in the mid-dorsal region and a dark coloured paired kidneys below the pericardium.

(ii) *Gills.* Gills are a pair of long, thin, double plate like structures, which hang freely into the mantle cavity on each side from the visceral mass. There is sieve-like arrangement in the gills with minute apertures, covered by cilia. The line of attachment of the gills to the visceral mass forms a horizontal partition dividing the mantle cavity in a large ventral infra-branchial chamber and a small dorsal *suprabranchial* or *cloacal chamber*.

(iii) *Foot.* The foot is a muscular structure projecting from the ventral surface. Its size and form are very variable depending upon the life of the animal. The mass of the foot is invaded by a portion of viscera, at least the alimentary canal and liver superficially the gonads in the life of animal.

(iv) *Head.* A distinct head is absent in *Unio*. The eyes and tentacles are also absent. The large mouth opens beneath the anterior adductor muscle. It is boarded by a pair of broad, lamellar labial palps on each side.

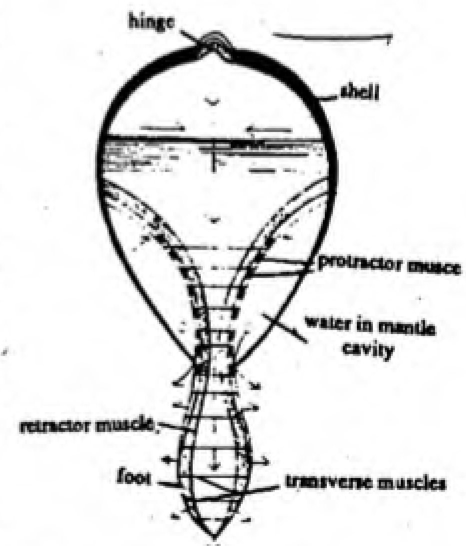


Fig. 63.4 *Unio*. Diagramatic, T.S.

LOCOMOTION

The locomotion is performed by muscular foot. It is effected by a combination of blood pressure and muscle action. Engorgement of the foot with blood, coupled

with the action of pair of pedal protractor muscles, produces extension. The water in mantle cavity and the blood act as a hydrostatic skeleton. The pressure of these two fluids is eleavted by the adducted valves. Blood from the visceral mass is forced down into the pedal haemocoel, causing the foot to dilate and anchor into the sub-stratum.

Withdrawl of the foot is effected by the contraction of an anterior pair and a posterior pair of retractors, which are also attached to the foot and shell. The scars of the pedal retractors are situated just above those of adductors.

COLELOM

Coelom is greatly reduced due to the development of connective tissue, unstriated muscle-fibres and blood-sinuses. Coelom is a haemocoel, filled with blood. It is represented by three small cavities: (a) a single ovoidal chamber, called *pericardium*, which is situated dorsally and in it, heart is located, (b) the cavities of the kidney or *urocoel*, (c) *gonocoels* or cavities of gonads. Originally, all the three were intercommunicated but due to gradual separation, the cavities of the gonads are completely separated, while the cavities of kidney and pericardium are inter-communicated.

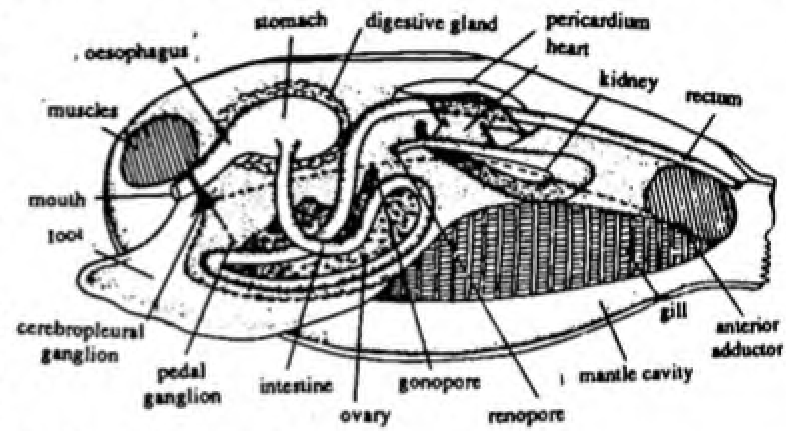


Fig. 63.5 *Unio*. Disected to show viscera.

DIGESTIVE SYSTEM

The digestive system comprises of alimentary canal and a paired digestive gland.

I. **Alimentary canal.** The alimentary canal is complete. It is a coiled tube of varying diameter and starts from mouth and terminates into an anus. Buccal cavity, jaws, radula and salivary glands are absent.

1. *Mouth.* The mouth lies at the anterior end of the visceral mass just below the posterior border of the anterior adductor muscle. It is bounded on either side by two soft, flat, triangular flaps called the outer and inner *labial palps*. The outer palps of the two sides unite above the mouth to from the upper lip. The inner palps of the two sides likewise fuse below the mouth to form lower lip. The outer surface of the palps is heavily ciliated. The mouth leads into the oesophagus.

2. *Oesophagus.* The oesophagus is a short, wide ciliated tube, which leads into stomach. The radula is absent as it is useless for the animal since it feeds on minute organisms.

3. *Stomach.* The stomach is a wide thick-walled rounded sac, situated dorsally in the visceral mass and is surrounded by paired digestive glands. The stomach is produced into a pouch-like outgrowth known as *pyloric caecum*. It contains a transparent gelatinous flexible rod called the *crystalline style*. It has proteinous matrix deposited with amylase which is a carbohydrate splitting enzyme. The style rorates due to cilia of the stomach and brings about the mixing of enzymes with food. The crystalline style is secreted by the cells of the stomach and is contained in a style sac.

4. *Intestine.* From the posterior end of stomach arises the intestine and enters the substance of foot where it coils on itself and again ascend the place where the pericardial cacity starts. It then runs dorsally again and is continued into the rectum.

5. *Rectum.* It is the terminal part of intestine which starts from pericardium and runs for a short distance before opening finally through the anus in the cloacal chamber. Internally the rectum has a ridge, the typhlosole.

6. *Anus.* The anus is situated on an anal papilla just above the adductor muscle.

II. Digestive glands

The digestive glands are a pair of large irregular green or dark- brown masses situated on the sides of the stomach. They lead into anterior part of stomach by many ducts. They are made up of highly branched tubules, lined by columnar epithelium of unequal height and containing basal nuclei. The cells of these glands also swallow the food particles and break the solid particles in addition to the secretion of enzymes. These cells intracellularly digest the protein and fats, and absorb the carbohydrates.

Food and feeding. Freshwater mussel is a ciliary feeder, feeding upon micro-organisms and organic debris which is filtered from the respiratory nutritive current of water drawn into mantle cavity. A continuous current of water is maintained mainly by the action of lateral cilia of gill filaments. As the water current enters the mantle cavity through the inhalent siphon it slows down and the solid food particles settle down over the gill surface. These are removed to the edge of mantle where they are pushed back and are expelled out. The lighter food particles get entangled into the mucus secreted by the gills. By the beating of the cilia of labial palps, the mucus is drawn towards mouth. The particles of food which cannot be digested are dropped down into the mantle cavity, whereas the digestible particles are pushed into the mouth along the deep ciliated grooves between the labial palps.

DIGESTION

The digestion is intracellular. Food from the stomach enters the digestive gland, the cells of which readily ingested and break down solid particles. Protein and fat digestion is exclusively intracellular, and the cells of gland also absorb carbohydrates. The only extracellular enzyme is the carbohydrate digesting enzyme (amylase) released in the stomach by the dissolution of the crystelline style. The style pouch is lined with cilia, the beating of which rorates the style and moves it forward with the result that its free end constantly rubs against a particular portion of the stomach wall and its head is worn away getting mixed with stomach content. Digested food diffuses from the gland into the blood for distribution.

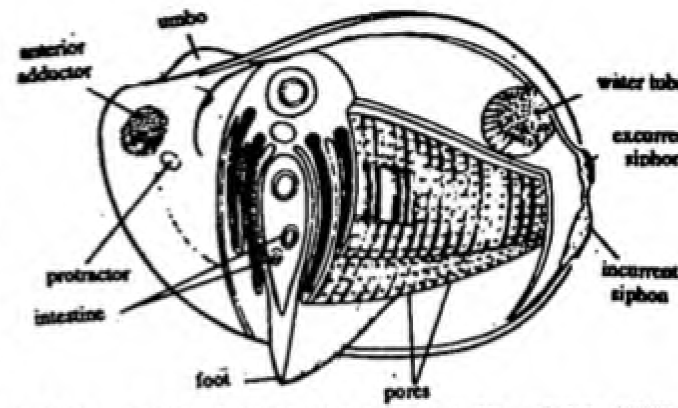


Fig. 63.6 A schematic section of the mussel showing the respiratory organs. Water tubes have been exposed, whereas, the pores are highly magnified.

Undigested food particles are sent back into the stomach, whence they pass into the intestine and them into the rectum by ciliary action. Function of intestine or rectum is not properly understood. They may absorb water from faecal matters. From the rectum the faeces is passed through the anus into the cloaca, which it leaves with the outgoing current through exhalant siphon.

RESPIRATORY SYSTEM

The respiratory organ in Unio are a pair of gills or ctenida and mantle.

1. Ctenidia or gills

There are two gills that hang in the mantle cavity, one on either side between the mantle and visceral mass. The gills are plate- like hence they are called lemellibranchs. Each gill has a central axis and plate like structure on either side. Hence the gills are called bipectinate gills.

Each gill is a W-shaped structure. It consists of two plate-like structures called *laminae*. One lamina is situated on the inner side called the inner lamina and the other is situated on outer side and is called outer lamina. Each lamina is V-shaped structure and formed of two vertical plates called lamellae. The outer one is called outer lamella and the inner one is called inner lamella. The outer and inner lamellae are united together at their anterior, ventral and posterior edges, but are free dorsally. Each lamella is formed of a series of vertical filaments called gill filaments. The gill filaments of the two lamellae of a lamina are continuous at the free ventral side. The gill filaments are joined to one another by horizontal bars called inter-filamentar junctions. Two lamellae of a lamina are joined together by inter-lamellar junctions. The inter-lamellar junctions divide the cavity lying between the lamellae into vertical chambers called *water tubes*. Dorsally all the water tubes open into a large cavity called *supra-branchial chamber*. This chamber communicates to the exterior through the exhalant siphon. The portion of the mantle cavity lying below the gill is called *infrabranchial chamber* which communicates to the exterior through the inhalant siphon. The lamellae are perforated by minute openings, the *ostia*. They are located

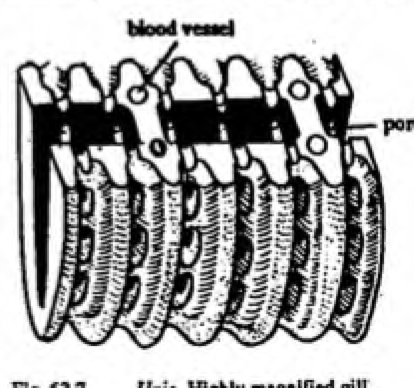


Fig. 63.7 *Unio*. Highly magnified gill.

between the gills filaments and inter filamentar junctions. Through ostia, water tubes open into the mantle cavity.

Each gill filament is covered by a layer of ciliated epithelial cells. Internally the gill filament is supported by chitinous rods.

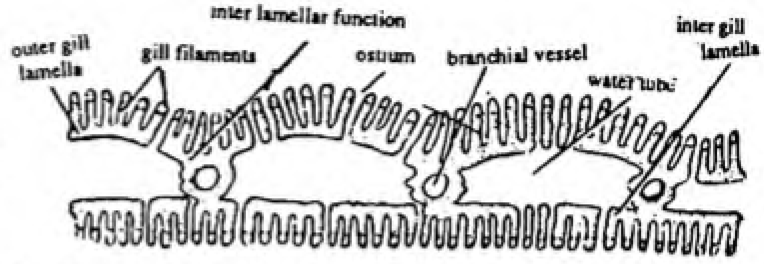


Fig. 63.8 *Unio*. T.S. of outer gill lamella.

Attachment of gills

The mode of the attachment of the gills is very peculiar, as it determines the course of the water-current in the body. The outer lamella of the outer lamina is attached to the mantle along the whole length by its upper edge from anterior to the posterior end. Inner lamella of the outer lamina and the outer lamella of the inner lamina are attached to the sides of the visceral mass a little below the origin of the mantle by dorsal edges. The inner lamella of the inner lamina is attached to the visceral mass in the anterior region, but is free in posterior region. Behind the posterior margin of the visceral mass inner lamella of inner lamina is also attached to its fellow of the opposite side. The inner lamina are attached together by their dorsal edge to the posterior adductor muscles on the sides of the visceral mass a little below the origin of the mantle. The outer lamella of the outer lamina is attached to the whole length of the mantle. The cavity between the upper edge of gill-lamella and the upper part of the mantle is called supra-branchial chamber, which continues posteriorly with the exhalent siphon.

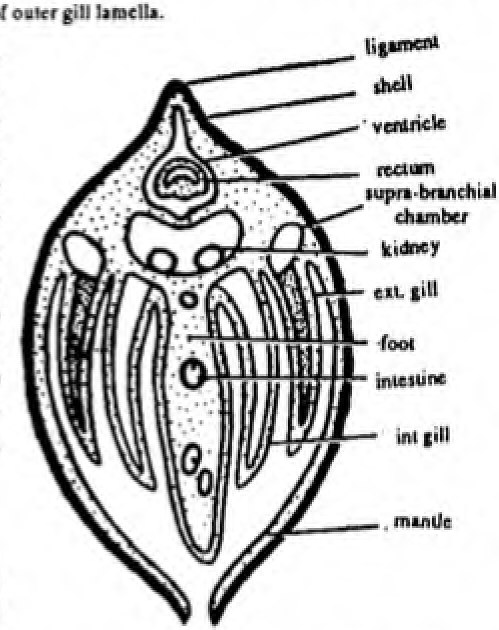


Fig. 63.9 T.S. of *Unio* through anterior region.

Blood supply

The gill receives venous blood from the kidney by the afferent branchial vessels and the oxygenated blood is conveyed to the heart by efferent branchial vessels.

Course of Water current

Beating of cilia of the gill filaments draws a continuous current of water into the infra-branchial chamber through the inhalent siphon. From here it enters the gills through ostia. Inside the gill, the water fills in the watertubes and flows out into the supra-branchial chamber are dorsal to each gill lamina and open posteriorly into the cloacal chamber. The water finally leaves the cloacal chamber through exhalent siphon which discharges water to the exterior.

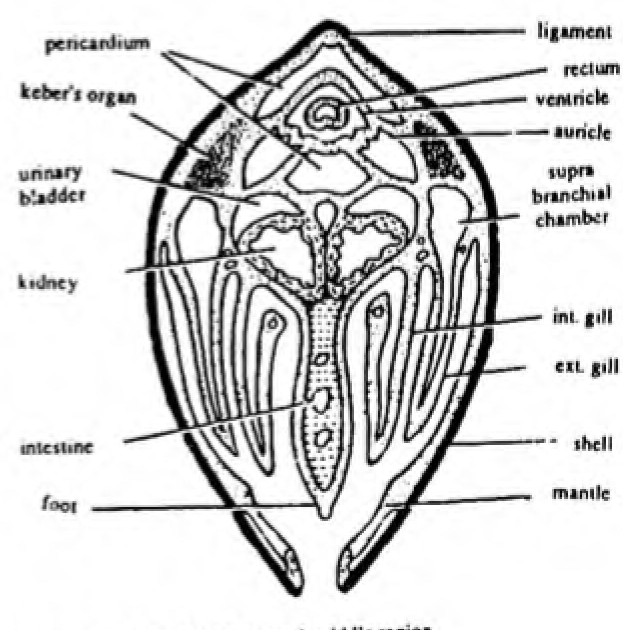


Fig. 63.10 T.S. of *Unio* through middle region.

CIRCULATORY SYSTEM

The circulatory system of Union is said to be open type because the capillaries are absent. The circulatory system comprises three parts.

1. Heart
2. Blood Vessles
3. Blood

1. **Heart.** The heart is situated dorsally near the posterior adductor muscle. It is enclosed in pericardium. The pericardium is a thin- walled triangular chamber. It is lined by epithelium and is filled with a fluid and represents a part of coelom. It is communicated with the supra-branchial chamber through the kidneys.

The heart is three chambered, having two auricles or atria and a ventricle. The auricles are thin-walled, highly distensible, triangular chambers one on either side of ventricle. They are attached by their broad bases to the pericardium and open dorsally into the ventricle. Each auriculo-ventricular aperture is provided with a valve that opens towards the ventricle and prevents the backward flow of blood. The ventricle has the form of a horizontal tube and surrounds a part of rectum.

The heart consists of smooth muscle-fibres covered externally by an epithelium called the epicardium. Endocardium is absent. The heart beats 20-100 times per minutes.

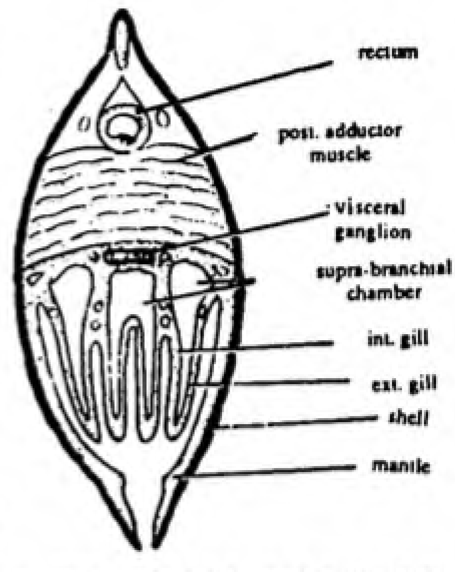


Fig. 63.11 T.S. of *Unio* through posterior region.

2. **Blood vessels.** The blood vessels comprises the (i) arteries (ii) sinuses (iii) veins.

(i) *Arteries.* From each end of ventricle arises, the *anterior aorta* passing above and *posterior aorta* below the retum. The anterior aorta supplies to the anterior parts of the body i.e. mantle, foot and viceral mass by *anterior pallial, pedal* and *visceral arteries.* The posterior aorta supplies to the posterior parts of the body i.e. rectum, mantle, nephidia, pericardium etc. by *rectal, posterior pallial, nephridia, pericardial arteries.*

(ii) *Sinuses.* The arteries ramify all the organs and finally empty into sinuses. From small sinuses blood is returned by larger sinues. The sinuses lack the epithelial lining of true blood vessels and connect directly with veins.

(iii) *Venis.* Blood from different parts of body is collected by many small veins in the end it reaches the large vein called vena cava which is placed longitudinally in the body. The vena cava is situated below the pericardium and between the kidneys. The blood from vena cava is send to kidneys by the renal vein, here nitrogenous wastes are removed. Blood from kidneys is sent to the gills for aeration by *afferent branchial vein.* Which gives off branches to all the gill-filaments. The oxygenated blood is sent to the auricles by *efferent branchaial veins.* Some deoxygenated blood is also sent directly to the auricles by vena cava. Blood from each mantle lobe is collected by a pallial vein, which also opens into the auricle of its side.

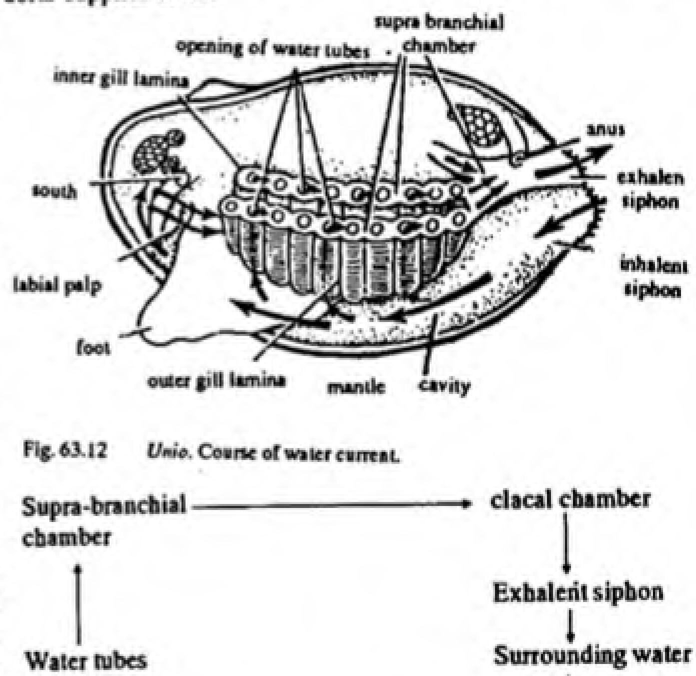


Fig. 63.12 *Unio*. Course of water current.

Supra-branchial chamber → clacal chamber
↓
Exhalent siphon
↓
Surrounding water
↓
Inhalent siphon → Sub-branchial or infra-branchia → Ostia → Water tubes (inside Gills) → Supra-branchial chamber

3. **Blood.** The blood consists of plasma and corpuscles.
The plasma is colourless in some species where as faint blue in others due to presence of haemocyanin, a respiratory pigment. The cospuscles are colourless and amoeboid hence called the leucocytes. Some are granular other non-granular. Blood helps in transporatation of food, oxygen, carbon dioxide and waste products, corpuscles help in phagocytosis of microorganisms.

Course of circulation. The auricles receive the purified blood and the ventricle pumps it to the various body organs in both forward and backward directions. The various veins and sinuses collect the blood from body organs and carry it to the kidney and gills for purification. The course of blood is again carried to the auricles. The course of blood circulation can be shown as

under:

EXCRETORY SYSTEM

In *Unio* followings are the excretory organs:

1. A pair of kidneys or organs of Bojanus

2. Keber's organ

1. Kidneys

The kidneys or organs of Bojanus (after the name of their discoverer) are situated below the pericardial cavity on either side of vena cava. These are brownish-black in colour. *Black* discovered these structure which are coelomic in origin. Each nephridium is a broad, U-shaped tube with its loop posterior, two ends anterior and two limbs situated purallel and one above the other. The lower limb of the tube is brown, spongy, thick walled, glandular in nature and forms the actual excretory part of the kidney proper. The upper limb is non-glandular lined by ciliated epithelium and is thin-walled and serves as ureter or urinary bladder. The kidney proper opens into the pericardium by a small, ciliated aperture known as reno-pericardial aperture. The ureter opens into the supra-branchial cavity by a small renal aperture between inner gill lamina and visceral mass.

The ventral glandular part of the kidney extracts nitrogenous products and guanin from the pericardial fluid and the blood. The ciliated epithelial lining of the bladder creates an outgoing current, which carries excretory fluid to the outside.

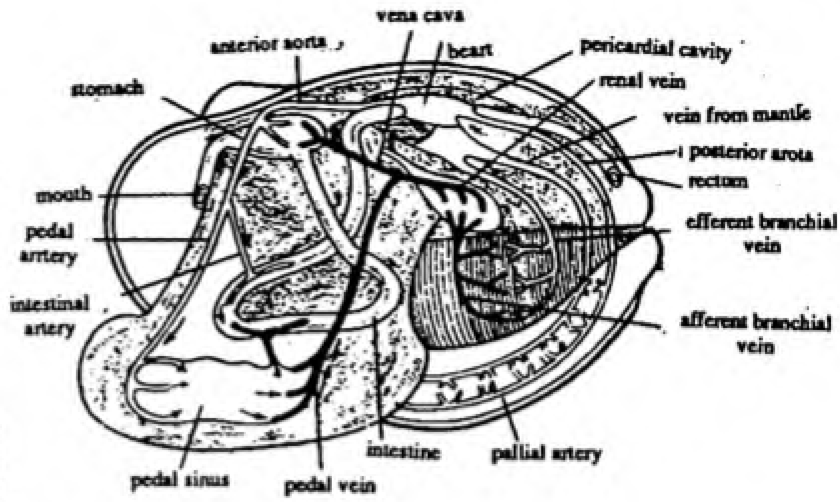


Fig. 63.13 *Unio* circulatory system.

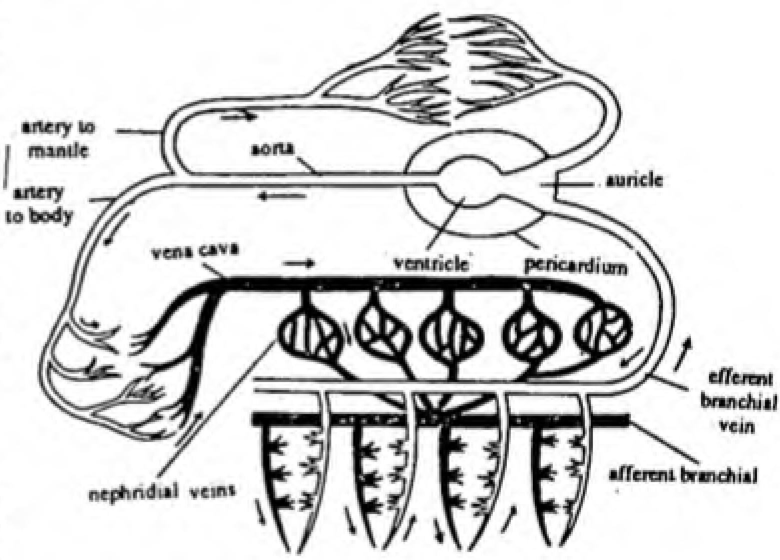
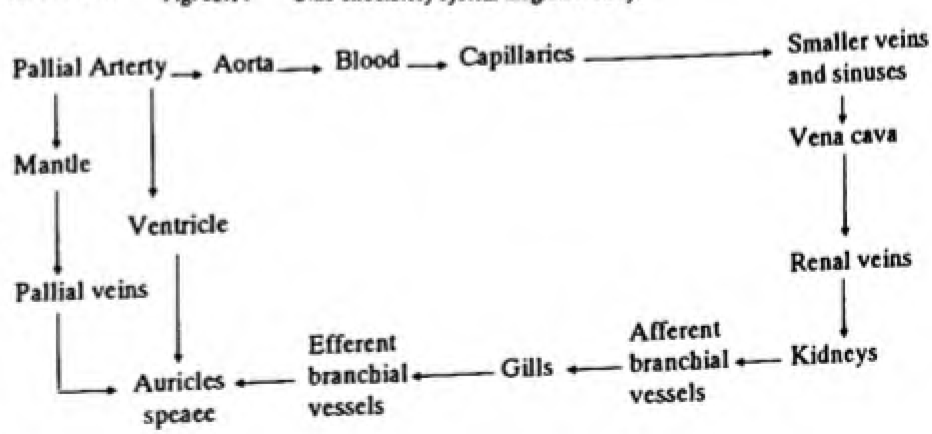


Fig. 63.14 *Unio* circulatory system diagrametically.



2. Keber's Organ

Keber's organ is a large reddish-brown gland situated in front of pericardium. It discharges waste products in the pericardium, whence it is eleminated via kidneys.

NERVOUS SYSTEM

Due to sluggish, sedentary life, the nervous system of *Unio* is greatly

reduced. It consists of three pairs of ganglia, connectives and commissures. These are:

1. Cerebro-pleural ganglia

At the base of the labial palps, just outside the corners of the mouth on either side, is placed a small yellowish, somewhat triangular cerebropleural ganglion. Each is formed by the fusion of two gnaglia a cerebral and a pleural. The ganglia of both the sides are equivalent of the brain. They are connected with each other by a thin transverse cerebral commissure, which passes over the oesophagus. Each cerebro-pleural ganglion gives out - (i) an anterior adductor nerve to the corresponding muscle, (ii) a labial nerve to the labial palp, and (iii) an anterior pallial nerve to the anterior part of the mantle. Besides, each ganglion gives off two conspicuous connectives, a cerebro-visceral connective which runs posteriorly to unite with the viseral ganglion of that side, and a cerebro-pedal connective which passes ventrally into the foot to unite with the pedal ganglion of the same side.

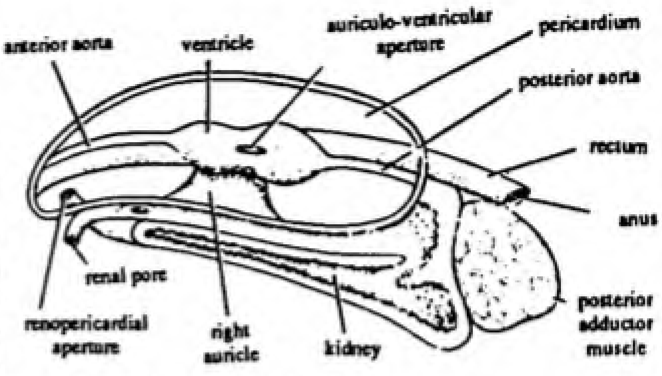


Fig. 63.15 *Unio* excretory system.

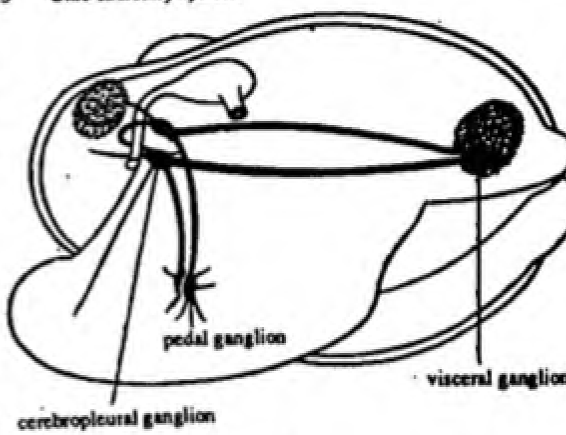


Fig. 63.16 *Unio*. Nervous system.

2. Pedal ganglia

The pedal ganglia are situated in the foot about 1/3 from its anterior end. They are present above muscular part and below the visceral mass. Both the pedal ganglia are closely associated so as to form a bilobed mass which supplies the nerves to the foot, its muscles and the statocysts. Each pedal ganglion is connected to the cerebro pleural ganglion of its side by the cerebro-pedal connective.

3. Visceral ganglia

A pair of visceral ganglia are situated mid-ventrally on the posterior adductor muscles. The visceral ganglia are fused together to form a flattened, somewhat rectangular mass. On each side, the visceral ganglionic mass gives off (i) a dorsal pallial nerve, (ii) a posterior pallial nerve to the posterior part of the mantle, (iii) a posterior renal nerve to the kidney, (iv) branchial nerve to the gill. It is connected with the cerebropleural ganglion of its side by a thin cerebro-visceral connective which gives off several small nerves to the visceral mass.

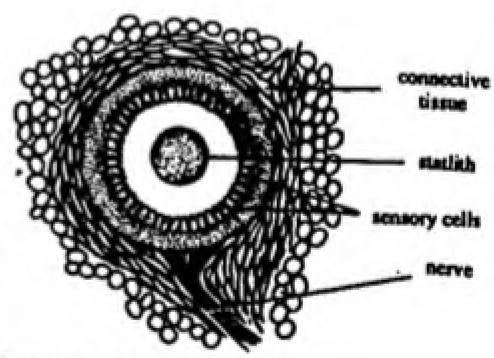


Fig. 63.17 *Unio*. Statocyst.

Autonomous nervous system. Recently, *E.J. Thomas* (1974) has worked out anatomy of *Lamellidens* and has reported presence of minor ganglia in the chief muscles and has suggested that they are autonomous.

Sense Organs

The sense organs are poorly developed due to sedentary mode of life. The main sensory structures are (i) Statocysts (ii) Osphariaium and (iii) Sensory cells.

1. Statocysts

The foot contains a pair of minute hollow vesicles, the statocysts, one close to each pedal ganglion. They are innervated by the cerebropedal connectives. The statocyst is lined by sensory cells and contains a mass of lime, called *statolith*, the movement

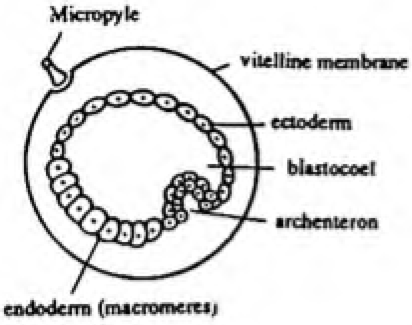


Fig. 63.18 *Unio*. A gastrula

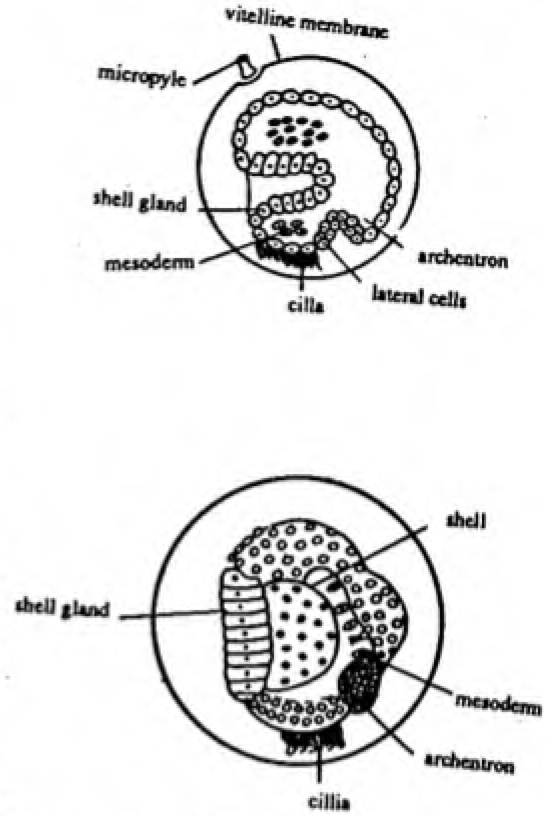


Fig. 63.19 *Unio*. A early and late embryo.

of which stimulates the sensory cells. The statocysts are thought to be organs of *equilibrium*.

(ii) Ospharidium

A pair of dark yellow masses of sensory epithelial cells are found at the base of gills on the ventral surface of the posterior adductor muscle and above the visceral ganglionic mass. The ospheridium is a chaemoreceptor as it tests the chemical nature of water entering the mantle cavity by way of the inhalant siphon.

(iii) Sensory cells

There are also other light responding devices found in the edges of mantle lobe and abundant on the inhalant siphon. They are regarded to be tactile organs and are also sensitive to light.

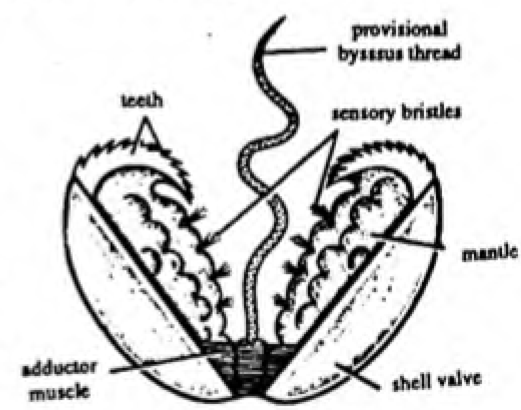


Fig. 63.20 *Unio*. A glochidium larva.

REPRODUCTIVE SYSTEM

The *Unio* is dioecious i.e. sexes are separate. The reproductive organs consist of the gonads and their ducts.

Male reproductive organs. These consist of a pair of testis which are white-coloured, highly branched, glandular masses situated in the visceral mass between the loops of intestine. From each testis a vas deferens arises which opens into the supra-branchial chambers by male genital pore situated in front of renel aperture.

Female reproductive organs. These are a pair of pink coloured glandular mass of branched tubules occupying the same position as testes in male. These become greatly enlarged during breeding season. Each ovary gives out an oviduct which opens by female genital aperture situated in front of renal opening. The accessory reproductive organs are absent.

Fertilization

The eggs are fertilized in the outer gill laminae. The eggs are collected in the supra-branchial chamber from here they reach the water tubes of the outer gill-laminae and are held there by the mucous. The sperms come out of the body of male body along with outgoing current of water. Some of these reach the gill laminae of the female through the incurrent siphon with water current and fertilize the eggs.

Development

The fertilized ovum undergoes segmentation. The cleavage is complete (holoblastic) but unequal. A hollow, spherical embryo, the blastula with a fluid filled cavity the blastocoel is formed. The bigger blastomeres are called macromeres and the smaller ones, micromeres. In gastrulation some of the macromeres are invaginated, resulting in the formation of an exceedingly small cavity, the *archenteron*. Later on there is an extensive invagination of macromeres which very greatly reduces the blastocoelic cavity. This is the rudiment of shell gland. Some large cells are budded off into the blastocoel, where they aggregate to form mesoderm. The invagination of the macromeres which constitute the rudiment of the shell gland, marks the dorsal surface of embryo, while the posterior end is marked by a tuft of cilia. The cells of the shell gland, which are tall, columnar, secrete an unpaired shell. Later arises a shell consisting of two valves, which are more or less triangular in appearence and have their ventral ends sharply incurved to form hooks that bear spines. The mass of cells consisting the embryo is divided into two on the ventral aspect, but remains undivided dorsally. The two ventral halves are the rudiments of mantle lobes. These bear peculiar brush-like sense organs. A long, thread-like adhesive organ, the *provisional byssus* appear on the ventral surface of the body. The mesoderm produces a large adductor muscle that stratches between the two valves of the shell. While in the lamina, which serves as a brood pouch the larva, called *glochidium*, is nourished by the secretions of laminar wall but on escaping from the body of mother through the exhalent siphon, it starts leading an ectoparasitic life on the body of some fish, which is persisted till its metamorphosis into adult. The glochidium is a minute larva 0.1-0.5 mm wide.

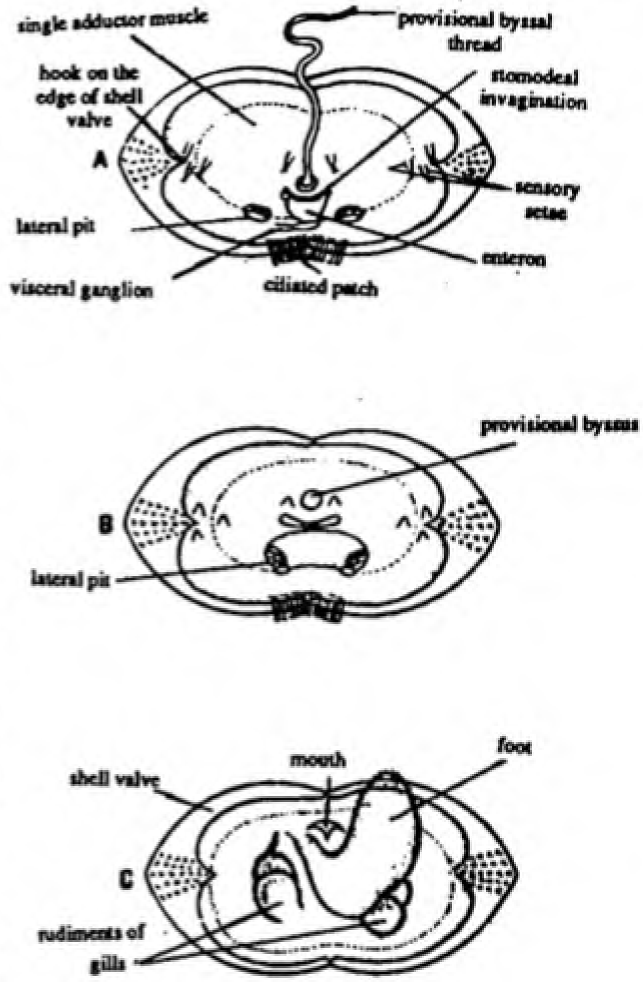


Fig. 63.21 *Unio*. Three stages in metamorphosis.

Metamorphosis

After some time the larva undergoes metamorphosis, which, as usual, consists of drastic structural alternations in the organisation of the body. The byssus and sense organs disappear. The mouth and anus are formed. Formation of mouth is formed by the invagination of ectoderm behind the byssus giving rise to stomodaeum, but no proctodaeum is formed, the anus formed by the perforation of poeterior end of the archenteric cavity and the overlying ectoderm. The foot arises as a projection from the mid- ventral surface behind the mouth and on either side of it are formed the rudiments of the gills.

The glochidium continue to lead its ectoparasitic life to the end of its larval period, after the completion of metamosphosis it leaves the host and begins its independent life, growing on the adult state. The time taken by larva to metamorphose into little clams is about 10 weeks.

Significance of glochidium

Glochidium is an ectoparasitic larval stage on a fish host. It helps in dispersal, protection and means of nourishment.

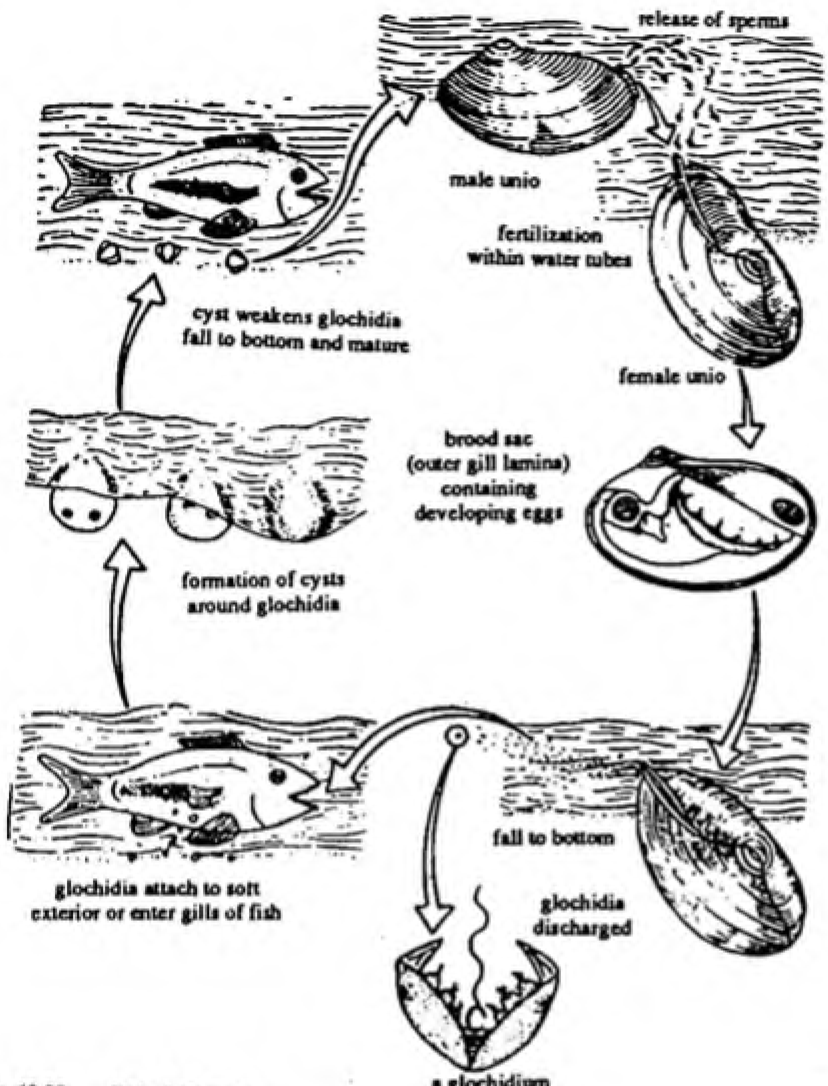


Fig. 63.22 *Unio*. Life cycle.

64

SEPIA

Sepia comes under class Cephalopoda in which the foot is transformed into circum-oral appendages completely surrounding the head and the epipodium is modified term as funnel or siphon or exhalent muscular tube.

SYSTEMATIC POSITION

Phylum	-	Mollusca
Class	-	Cephalopoda
Sub class	-	Dibranchiata
Order	-	Decapoda
Genus	-	*Sepia*

DISTRIBUTION

Sepia is commonly called cuttle fish. It is cosmopolitan in its distribution and is more common in warmer seas like Mediterranean, Indian ocean, Pacific etc.

HABITS AND HABITATS

Sepia is a marine mollusc. It inhibits shallow waters usually living between stones and in crevices of rocks but often burrows in sand.

It is a good swimmer. The swimming movements are forward and backwards by the fins and funnels. It feeds on crustaceans and fishes. It is capable of colour changing. When followed by an enemy, it discharges into water ink from the ink gland. Sexes are separate. Breeding occurs in summer.

EXTERNAL FEATURES

Shape and size. *Sepia* has a fishy, bilaterally symmetrical and dorsoventrally flattened body. The anterior and posterior ends of the body, infact, represent the dorsal and ventral ends due to much elongation of dorso-ventral axis of the body. The body- colour is brownish and it is about 20 cm. in length.

The body is divisible into three parts:

1. Head

2. Neck

3. Trunk

1. *Head.* The head is almost globular in form. It bears a pair of large, highly developed eyes at the sides and mouth at its free end. The mouth is surrounded by five pairs of muscular processes. These are differentiated into four pairs of short and stout arms and one pair of long tentacles retractile into large pits at their bases. When extended, they are about 2/3 of the length of the body. They have strongly convex outer surface and flat inner surface. The inner surface bears four longitudinal rows

of suckers. Each sucker is a muscular, shallow cup with a narrow, horny rim and supported on a short, thick stalk. The tentacles bear sucker on their expanded club-like tips only. The tentacles are used in the capture of prey and in copulation. The left arm of the fifth (posterior) pair is slightly modified in the male. The moification simply pertains to the loss of some of the suckers. This arm is called as hectocotylized and is used for transferring spermatophores into the mantle cavity of female. The arms, tentacles and the head proper are collectively called cephalopodium. Some workers regard arms as the main parts of the foot.

However, it has been suggested that arms should not be described as modified parts of foot but as cephalic appendages. According to this view, the funnel or siphon should be regarded as the molluscan foot, hence the name Siphonopoda has been suggested by some authors. The funnel is situated on the posterio - ventral side behind the head and is regarded a modified part of foot.

2. *Neck.* It connects the head with trunk. It bears a funnel which opens to out side by a narrow aperture and by a large aperture into mantle cavity.
3. *Trunk.* The trunk is elongated somewhat flattened and shield-shaped. Its broad base is directed orally and the pointed apex aboally. It is bordered by a narrow fin on either side which helps in locomotion at leisure. One side of trunk is darker, slightly convex and hard due to the presence of shell inside.

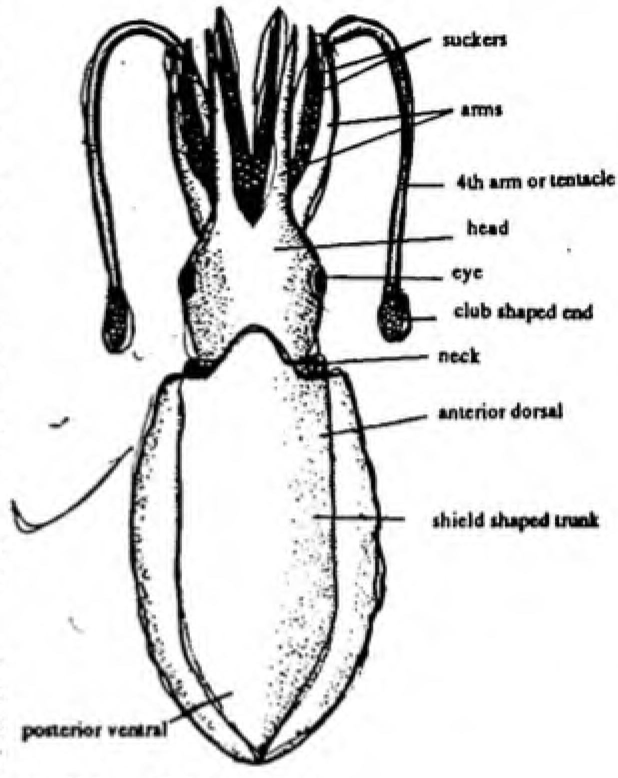


Fig. 64.1 *Sepia.* Dorsal view.

Mantle

The trunk is covered by a thick fold of mantle, which terminates towards the oral surface in a ridge around the neck. The head can be partially retracted. Posteriorly the ridge forms a large cavity bounded by the mantle called the mantle cacity, later contains the entire viscera.

Funnel

Below the head lies a large conical muscular tube, the funnel or siphon projecting beyond the neck. It internally communicates with the mantle cavity by a wide aperture, thus the funnel is the main out-let of the mantle cavity. A pair of cartilaginous knobs on the mantle fits into corresponding sockets on the posterior ventral surface of the funnel. The funnel does not only carry to the exterior the foul water of respiration, the faecal matters and the products of excretory and reproductive organs but also takes an important part in locomotion.

Skin

Flat contractile, pigment-containing cells, the *chromatophores* occur in the deeper layers of the integument over the entire surface. They have elastic membrane from which bundles of muscle- fibres radiate to the surrounding tissue. The chromatophores are of three kinds reddish, yellowish-brown and orange. They can be detailed by the contraction of rediating muscles. The living *Sepia* can change its colour. Besides the

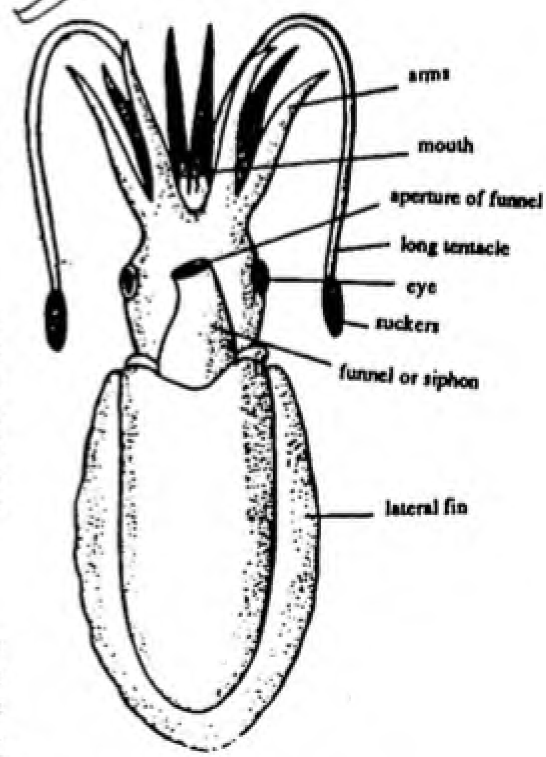


Fig. 64.2 *Sepia.* Ventral view.

chromatophpores, a number of cells, the *iridocytes* are present in the integument which cause the peculiar iridescence in addition to the vivid colouration caused by the chromatophores.

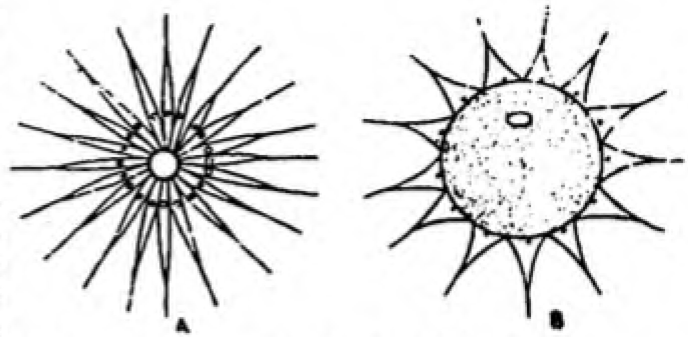


Fig. 64.3 *Sepia.* Chromataphore. A—contracted, B—expanded.

Shell

The shell is internal and is called the *cuttlebone* or *sepiostaire.* It is enclosed in a sac of mantle on the anterior surface of the trunk. It is secreted by the sac itself. It is flat and roughly oval in form with rounded oval end the *postracum* and a pointed aboral end, which has a sharp spine or *rostrum.*

The shell is non-living and consists of a large number of closely arranged calcareous laminae. The laminae enclose air-spaces between them to make the shell-light. Thus the shell besides acting as endoskeleton also serves as a float and help to maintain equilibrium of the body being dorsal in position. The shells of dead *Sepia* are often found on the sea-coast thrown by the tides. These are often called the sea-foam.

MANTLE CAVITY

It is a large space enclosed between the trunk and the mantle on the ventral side. It is closed on all the sides except the oral side, where it communicates with the exterior by two passages arround the neck, the pallial aperture and a large tube-like funnel or siphon. The funnel has a wide internal opening and a narrow external opening. Basally, on its ventral surface, the funnel bears a pair of cartilaginous sockets, called the *funnel* or *infundibular cartilages.* Opposite them, on the internal surface of the reflected mantle folds, are seen a pair of oval cartilaginous knobs, the *mantle cartilages.* Similarly, the dorsal surface of neck carries the *nuchal cartilage*, which fits against the dorsal cartilage on the mantle. By enlarging the mantle cavity, the *Sepia* draws water into it through the pallial aperture. When the mantle cavity is reduced, the mantle and infunfibular cartilages get interlocked to close the pallial aperture. Therefore the water leaves the mantle cavity through the funnel. The funnel is guarded by a flap-like valve that opens out wards.

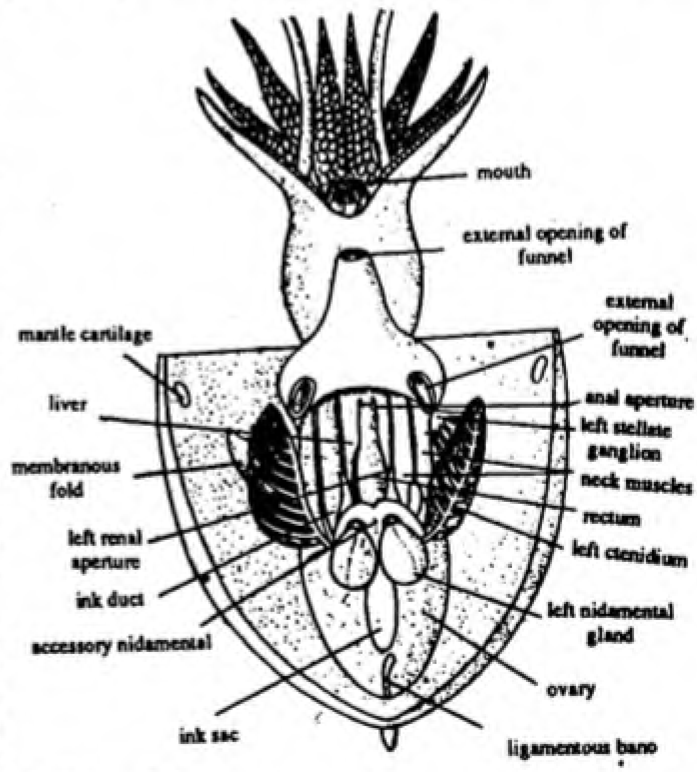


Fig. 64.4 *Sepia.* Showing viscera.

The whole of the mantle cavity is occupied by visceral mass having various organs. The digestive gland is situated anteriorly on either side of the retractor muscles of head and funnel. There is a pair of plume-shaped ctenidia situated posteriorly in the mantle cavity. Between the ctenidia is found anus. On each side of the anus there are thin openings of renal sac called renal pores or apertures situated on renal papilla. On the left hand side is the opening of genital aperture also situated on a papilla, penis is in the male and oviduct is found in female. On the mantle wall where neck joins the trunk are situated two large stellate ganglia one on each side. Posteriorly behind the *nidamental glands* is found an ink-sac which contains ink made of melanin pigment. The duct of the ink-sac, runs forward ventral to the rectum and opens it dorsally close to the anus. In male *Sepia*, testis is situated covered by an ink-sac while in female renal sac are invisible as they are hidden by nidamental glands and a pair of accessory inidamental glands.

LOCOMOTION

Sepia exhibits two types of locomotion. They are:

(i) By fins

(ii) By the funnel

(i) **By fins.** The fins which are fringed along the lateral margins of body. The fins bring about swimming by their undulations.

(ii) **By the funnel.** The funnel or siphon brings about backward darting movements. During this movement, the mantle cavity is filled with water. When the mantle contracts, the pallial aperture closes due to interlocking of the mantle and infundibular cartilages and this expels the water from the mantle cavity through the funnel as a jet. As the jet of water is forced forward, the animal is pushed backward. The animal can dart forward also by bending the siphon backward.

Fig. 64.5 *Sepia*. A jaw.

COELOM

It is a pouch being divided into oral and aboral parts by a constriction. The oral is the anterior part or pericardium in which heart is enclosed. It communicates with the cavities of the kidneys or renal sac by a pair of reno-pericardial apertures. The aboral part forms the gonocoel which encloses the gonads.

DIGESTIVE SYSTEM

The digestive system consists of

1. Alimentary canal

2. Digestive glands.

1. **Alimentary Canal.** The alimentary canal starts from mouth and terminates into anus. Mouth is present among the oral arms and is surrounded by a thin, fleshy circular lips beset with numerous papillae. Two jaws are located in the lips. The jaws have somewhat the appearence of the beak of a parrot. The month leads into a large thick-walled, muscular buccal cavity or pharynx. Buccal cavity contains on its floor the odontophore and the radula bearing numerous minute, horny teeth. The buccal cavity leads into the oesophagus, which is a long narrow tube. It runs straight towards the aboral end, passing between two lobes of liver. The oesophegus opens into a rounded thick walled muscullar bag, the stomach. The stomach is followed by the tubular intestine. At the junction of stomach and intestine, a wide, curved sac opens into the alimentary canal. It is known as caecum. The intestine runs forward into a rectum. The rectum opens into the mantle cavity by anus. A pair of leaf-like anal- valves project at the sides of anus. Their function is uncertain.

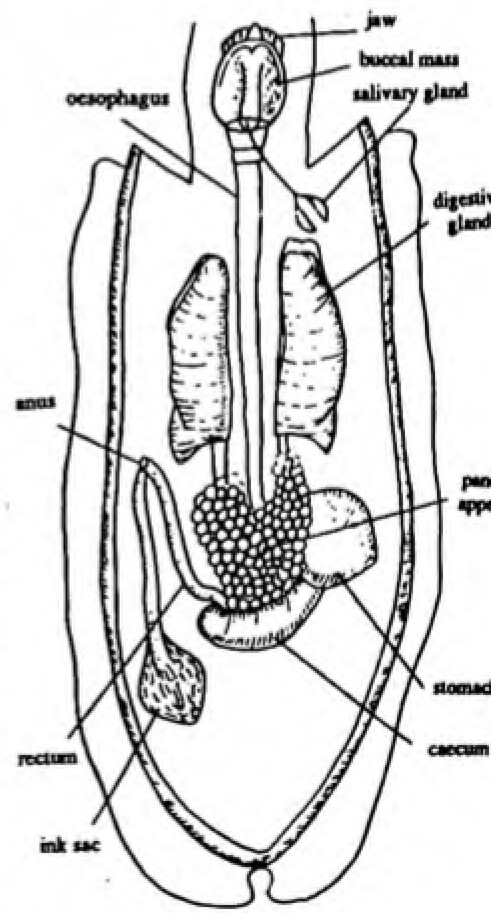


Fig. 64.6 *Sepia*. Alimentary canal.

2. **Digestive glands.** The glands associated with alimentary canal are:

(a) *Salivary glands.* A paired salivary glands are present in the head behind the cranial cartilage. A salivary duct leds inwards from each gland and joins its fellow from the opposite side to form medium salivary duct which opens into buccal cavity. The function of salivary glands related to saliva has not been mis-

named because their secretion is used to paralyse the prey hence these should be called poison glands.

(b) *Liver.* It is a large brownish organ extending from the vicinity of the salivary glands nearly to the aboral end of the body. It consists of two partly united right and left solid glandular portions, each of which is provided with a duct opening into the cavity of the alimentary canal opposite the point where stomach, caecum and intestine meet.

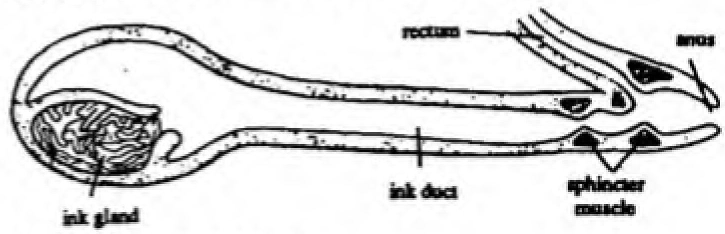


Fig. 64.7 *Sepia.* L.S. of ink gland.

(c) *Pancreas.* It is composed of numerous minute vesicles that surround the hepatic ducts and open into them.

(d) *Ink gland.* An ink-gland is situated in the ink-sac. Ink-sac is a pear-shaped gland situated below the thin integument of the anterior wall of the mantle cavity. It opens by a duct dorsally into the rectum close to the anus. The ink-gland secretes a brown or black fluid or ink. It contains a high concentration of melanin pigment and is stored in the ink sac. When startled, the cuttle fish discharges the ink, which mixes with water in the mantle cavity and passes out through the funnerl as a dark-cloud, under the cover of which the animal escapes from an enemy or approaches a prey.

Food. Food of *Sepia* consists of crustaceans eg., prawn and shrimps; molluscs and small fishes. Prey is caught by the protrusion of the tentacles. The prey is attached to the tentacles by the suckers and drawn in within the reach of the arm. Jaws which are situated in the mouth help in crushing the food, radula in grasping the flesh and in swallowing. A pair of salivary glands is also situated in *Sepia*. These glands produce a poison which kills the prey.

Digestion. The food caught by tentacles is paralysed by salivary glands, crushed into pieces by jaws swallowed with the help of radula, reaches the stomach where it is mixed with the digestive fluids from the liver and pancreas. The digestion is completed in the caecum where liquid products are absorbed while undigested food is passed into the intestine where some absorption may take place. The undigested food material thrown out of the anus. The hepato-pancreas secretes digestive enzymes and serves for the absorption and storage of the food and removal of waste products. The food stored in the liver is not directly absorbed but received through the blood.

RESPIRATORY SYSTEM

The respiratory organs are paired, large, plume-shaped ctenidia or gills, lying in the mantle cavity, one on either lateral sides. Each ctenidium is bipinnate, with numerous delicate lamellae on either side of a central axis. The respiratory surface of the lamellae is increased due to the presence of various folds on the lamellae. Internally the lamellae are not completely in contact with each other. Each gill receives venous blood through an afferent branchial vessel from the branchial heart of its side. The blood passes in a system of minute branches through the lamellae and is finally collected into an efferent branchial vessel leading to the auricle.

RESPIRATORY MECHANISM

The muscular mantle rhythmically contracts and expands, thus the mantle cavity alternately increases and decreased. When the mantle cavity enlarges, fresh water flows into it through the pallial aperture. This water passes over the ctenidia. Exchange of gases occur in the vascular lamelle. Carbondioxide is diffused out in the water and when the mantle contracts, the water is expelled out through the funnel.

CIRCULATORY SYSTEM

The circulatory system is well developed with a complete separation of venous and arterial blood. It consists of heart, blood vessels and a system of capillaries and blood.

Heart. There are three hearts; a large systemic or arterial heart and a pair of small branchial or venous hearts.

The systemic or arterial heart lies in the middle of the visceral mass enclosed in the pericardium. It is three chambered, having a large, median, thick-walled ventricle and two small lateral, thin-walled auricles. The ventricle is divided into two lobes

by a constriction. It supplies arterial blood through a large oral or cephalic aorta and a small aboral or posterior aorta to the anterior and posterior regions of body. The aurcles receives oxygenated blood by the efferent branchial veins. This blood passes into the ventricle and is send out via aortae.

The branchial hearts lie one at the base of each ctendium. They are simple contractile sacs that receive and supply deoxygenated blood by afferent branchial veins. A rounded glandular body called *appendage* is attached to each branchial heart.

Blood vessels. The oral and aborae aortae divides into small branches, the arteries, which divide the redivide to form very fine, microscopic vessels, the capillaries. The capillaries reunite to form large vessels, the veins. A large median vena cava returns blood from the head region. Infront of the rectum, it bifurcates into right and left afferent branchial veins, which run through the corresponding renal organs to the base of ctenidia. Here they dilate to form branchial hearts.

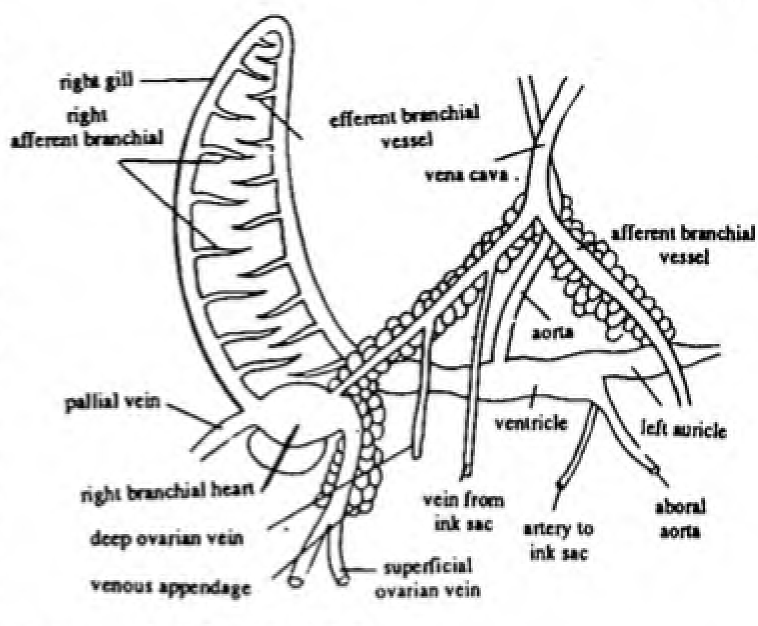


Fig. 64.8 *Sepia*. Circulatory system.

A pallial vein from the mantle and an abdominal vein from the posterior region pour the venous blood into each branchial heart. The right vena-cava or right branchial vein also receives a vein from ink-gland and gonads. Each branchial heart pumps the blood to the ctenidium of its side by an afferent branchial vein, which runs through the axis of gills and gives off branches. The oxygenated blood from the ctenidum is returned by an efferent branchial vein first to the auricle and then to the ventricle.

Blood. Blood consists of the plasma containing haemocyanin, dissolved in it. Colourless amoebocytes floating in it. It is colourless when deoxygenated and light blue when oxygenated.

EXCRETORY SYSTEM

The process of excretion is affected by a *kidney* or *renal sac* which consists of three thin-walled chambers communicating with one another. Out of them, one is dorsal and median while the other two are ventral and symmetrically situated on either side of the rectum. The two ventral parts of the kidney open to the outside by the renal apertures situated on the renal papillae. Through each ventral chamber passes the corresponding branchial vein of vena-cava. The vein is attached to the dorsal walls of the ventral renal chamber and are covered by glandular epithelium which is excretory in nature. The nitrogenous waste products are extracted by glandular walls and reaches into the renal sac. The dorsal chambers encloses the pancreatic follicles covering and opening into the ducts of the digestive gland. They are richly vascular and are said to serve an excretory function. The nitrogenous excretory matter in the cavities of renal sac is in the form of guanin which is poured into the mantle cavity.

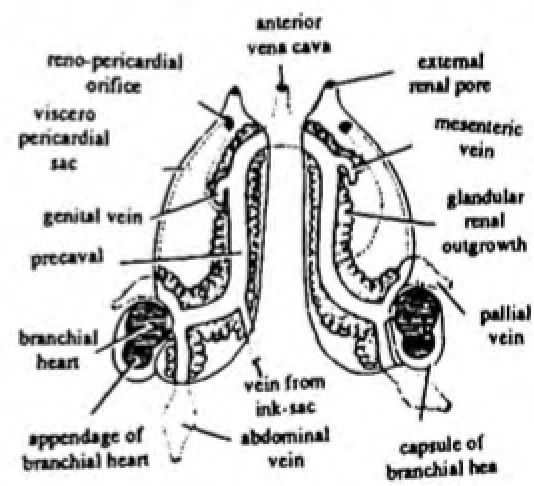


Fig. 64.9 *Sepia*. Excretory system.

NERVOUS SYSTEM

The nervous system shows a higher grade of organisation. The nervous system consists of ganglia, connectives and commissures. Following are the ganglia:

1. Cerebral ganglia

2. Pedal ganglia

3. Pleuro-visceral ganglia

4. Stellate ganglion or pallial ganglion

5. Gastric ganglion.

1. **Cerebral ganglia.** Paired cerebral ganglia are found together into a rounded mass lying in a hollow of the cranial cartilage and covered over anteriorly by a strong fibrous membrane. The brain gives off from the sides a pair of very short, thick optic nerves that at once expand into large optic ganglia lying in close contact with eyes. A small olfactory ganglion lies close to the optic ganglion and sends a fine olfactory nerve to the olfactory pits. The cerebral ganglia are connected with the superior-buccal ganglia anteriorly by thin cerebro-buccal commissures. The superior buccal ganglia are connected with a pair of closely united inferior buccal ganglia by a pair of circumoesophageal connectives join the brain with pedal and pleuro-visceral ganglia that lie posterior to oesophagus. A pair of nerves extend from the brain to the statocysts by way of the pedal ganglia.

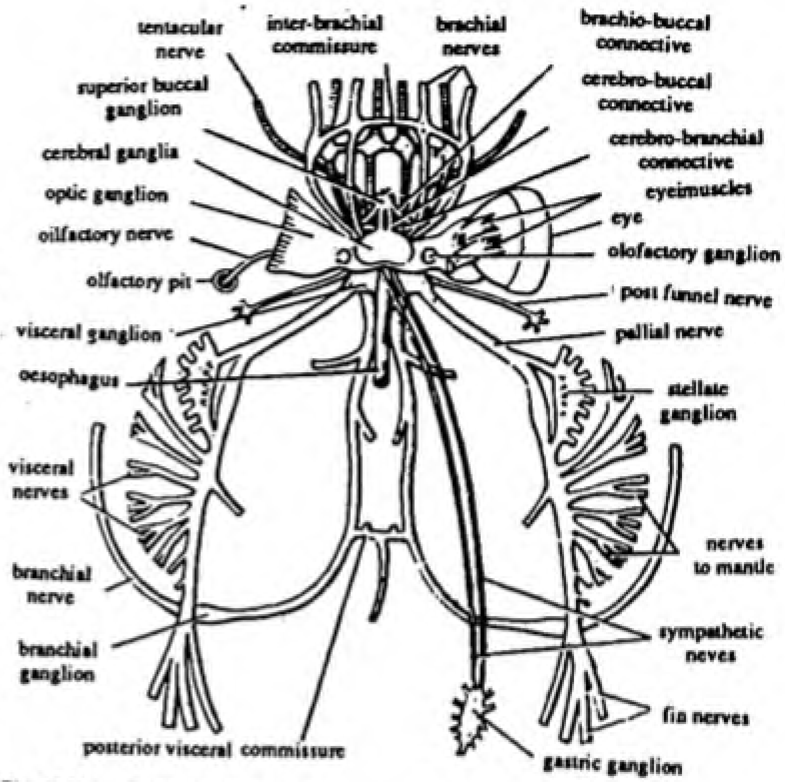


Fig. 64.10 *Sepia.* Nervous system.

2. **Pedal ganglia.** The pedal ganglia are fused into a mass. They send 10 branchial nerves to the arms. Each nerve expands into a branchial ganglion at the base of the arm it supplies. The pedal ganglia also give off a pair of infundibular nerves to the funnel. The pedal ganglia are connected with the superior buccal ganglia by bucco-pedal connectives and with the cerebral ganglia by cerebro-pedal connectives.

3. **Pleuro-visceral ganglia.** These are also united into a single mass being in immediate contact with the pedal behind the oesophagus. The pleurovisceral ganglia give off two visceral nerves innervating the various internal organs and forming a visceral loop from which arise a pair of branchial nerves, having each a branchial ganglion at the base of the ctenidium. The pleuro-vis- ceral ganglia also give off two very stout pallial nerves which innervate the mantle.

4. **Pallial ganglion.** Each pallial nerve runs through the neck to the inner surface of the mantle cavity and expand into a large, flat, pallial or satellate ganglion which is visible in front of the ctenidium when the mantle cavity is exposed.

5. **Gastric ganglion.** A pair of sympathetic nerves arise from the inferior buccal ganglia and extend aborally along the oesophagus to the stomach, where they meet the gastric ganglion.

SENSE ORGANS

The sense organs are highly developed in *Sepia*. These are eyes, statocysts, olfactory pits and a gustatory organ.

Eyes. Paired eyes are present. They are large, consepicuous structure projecting from the dorso-lateral sides of the head. Each eye is enclosed in an orbit formed by cartilages. The outer wall of the eye-ball is called the *sclerotic coat* which is supported by seclerotic cartilage. The sclerotic coat continues in front as the contracted *iris* with an opening called *pupil* in the centre. Pupil can be dilated or contracted by the muscles. Just in the inner region of the iris is situated a large spherical *lens* which consists of two plano-convex halves and supported by an annular process termed the *ciliary process*. *Choroid* which is the middle layer is absent in the eye of Sepia. The inner layer is the *retina* which is formed of a layer of parallel rods which bound the cavity of the eye externally with a layer of retinal cells in close association with the rods internally and the optic nerve fibres externally.

Immediately behind the eye-ball the optic nerve is enlarged and dilates to form optic gnaglion from which bundles of nerve fibres originate and innervate retinal cell through sclerotic wall. Small optic gland or white body of unknown function is also situated near the optic ganglion. The transparent horny part of the skin covering the upper exposed part of eye is called the secondary cornea or flase cornea. A fold of skin can be drawn like an eyelid over the false cornea to some extant. The cavity of eyeball is divided into two unequal parts: a small anterior chamber, filled with a watery *aquerous humour*, and a large posterior chamber filled with a jelly-like *vitreous humour*.

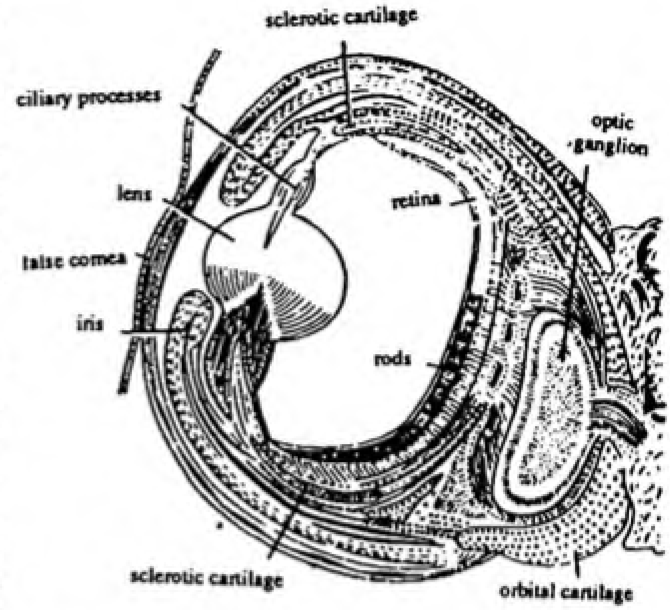


Fig. 64.11 *Sepia*. V.S. of eye.

Thus the eye of *Sepia* resembles those of vertebrate eye. However, the vertebrate eye is formed by the outgrowth of brain whereas the cephelopod eye is formed by an ectodermal invagination.

Statocysts. A pair of statocysts, which are organs of equilibrium, lie ventral to the pleuro-viseral ganglian. Each remains enclosed in cranial cartilage. A statocyst is a rounded sac, about 3 mm. in diameter. The inner surface is uneven and covered by flat cells, except on posterior side where two spots occur. These are crists, a statica and macula statica. These have large processes at the free ends and the other end produced into fine fibril that forms the statocyst nerve. A large dense statolith lies within the statocyst attached to the macula.

Olfactory pits. Small ciliated olfactory pits are situated posterior to the eyes. The sensory cells of the pits are innervated from small olfactory ganglia lying close to the optic ganglia.

GUSTATORY ORGANS

A small elevation covered with papillae on the floor of buccal cavity just infront of the odontophore is said to be the organ of taste.

REPRODUCTIVE SYSTEM

The *Sepia* is unisexual, but there is no prominant sexual dimorphism except that the males are smaller and possess slightly longer arms.

Male reproductive organs: The male reproductive organs comprise:

(i) Testis

(ii) Vas deferens

(iii) Vesicula seminalis

(iv) Prostate gland

(v) Needham's Sac

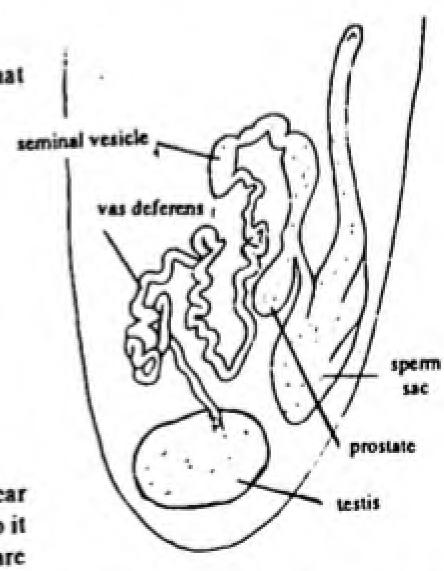


Fig. 64.12 *Sepia*. Male reproductive organs.

(i) *Testis.* The testis is large, oval, yellowish and saccular structure lies near the apex of visceral mass. It is enclosed in a coelomic sac and opens into it by a small aperture on its ventral side. The sperms produced in the testis are passed into the coelomic sac. The coelomic sac leads on the left side into a vas deferens.

(ii) *Vas deferens.* It is a narrow coiled tube, it leads into seminal vesicle.

(iii) *Vesicula seminalis.* It is a long tube. Here the sperms are rolled up into long and narrow bundles enclosed in elaborate chitinous capsules, called the spermatophore. A *spermetophore* is like an automatic bomb, at one end it has a complex spring-like arrangement which ruptures its wall as soon as transferred to water.

(iv) *Prostate glands.* The terminal end of vesicula seminalis gives off two blind folds, one of them is called the prostate gland.

(v) *Needham's sac.* The seminal vesicle terminates into a wide reservior, the Needham's sac lying on a papilla or the penis to the left of the anus.

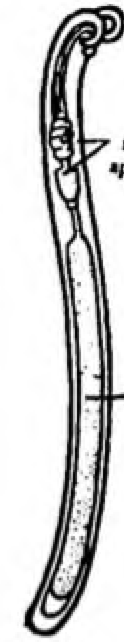


Fig. 64.13 *Sepia.* A spermatophore.

Female reproductive organs. The female reproductive organs comprise:

(i) Ovary

(ii) Oviduct

(iii) Nidamental gland

(iv) Accessory Nidamental glands

(i) *Ovary.* A large ovoid ovary situated, like the testis in the male in aboral region of the trunk. It is enclosed in a similar coelomic sac. It has an axial swelling that bears numerous follicles. Each follicle with a singel ovum supported on a stalk.

(ii) *Oviduct.* A wide thin-walled oviduct arises from the capsule or coelomic sac and runs orally to open into the mantle cavity by genital aperture.

(iii) *Nidamental glands.* A pair of large, flat, oval bodies lie on the anterior wall of the mantle cavity on the sides of ink-gland. These glands secrete a viscid material by means of which the eggs when deposits adhere together is masses.

(iv) *Accessory Nidamental glands.* A glandular mass of organe colour known as accessory nidamental glands lie at the sides and around the anterior sides of the nidamental glands. They open into the mantle cavity by a number of minute pores. Their function is not clear.

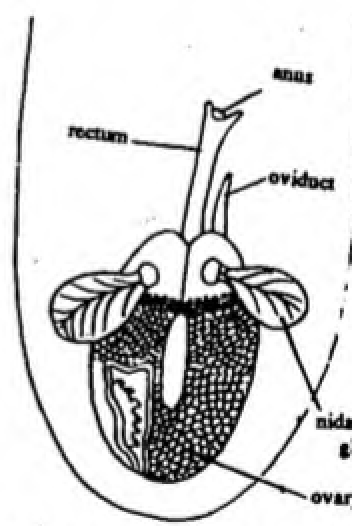


Fig. 64.14 *Sepia.* Female reproductive organs.

Copulation, fertilization and egg laying

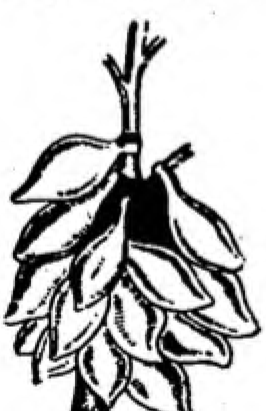


Fig. 64.15 *Sepia.* A egg mass.

In *Sepia* the 5th left arm of the male is hectocotylized i.e. modified for coculation by reduction of some of the basal rows of suckers. The male inserts it in its own mantle cavity to extract the spermatophores. Later on, this arm is inserted into the mantle cavity of the female and the spermatophores are deposited in bursa copulatrix, which is a modified part of the funnel. The speremetophore are burst by the spring apparatus in them, and release the sperms after copulation. When ripe ova are passed out side one by one from the ovary through the coelomic funnel, they fertilized. The viscid secretion of nidamental gland covers the eggs and cement them into a mass. These masses of eggs are attached by stalks to the twig of marine plants or weed or some other object.

The development is direct without larval stage.

65

PEARL AND PEARL INDUSTRY

A pearl is a conscretion produced by a mollusc. Its culture is paying industry these days. The oldest record of using pearls go back to the chinese people. They are said to have used them as far back as 2300 B.C. Royal families and nobles of every country in age have adorned their persons with pearls.

WHAT IS A PEARL ?

A pearl is a concretion formed by mollusc. It consists of nacre or mother of pearl as the mollusc shell. It is secreted by the mantle, the inner muscular lining of the shell, as a means of protection against foreign body. A faultless pearl is formed by the deposition of nacreous substances arranged one after the other in a concentric layer and laid down by the epithelium of mantle.

PEARL FORMATION

The pearl formation is an adaptation against outside materials. When a foreign material such as a sand-grain or a parasite happens to enter the body it adheres with the mantle. The mantle epithelium immediately grows over the material in the form of a sac and enclose it. The mantle epithelium start secreting concentric layers of nacre around the foreign material. The complete structure is called pearl.

COMPOSITION OF PEARL

The pearl is formed by nacre. The nacre is formed of two substances, the calcium carbonate which is in the form of argnoite or calcite and albuminoid substance called conchiolin ($C_{30}H_{42}N_2O_{11}$). The chemical analysis of the typical pearl is:

Calcium Carbonate	88-90%
Organic matter	3.8 - 5.9%
Water	2 - 3%
Residue	0.1 - 0.8%

TYPES OF PEARLS

Following are the four main types of pearls:

1. **Blister pearls.** When some foreign matter such as sand, worms, crabs, fish or pieces of shell becomes lodged between the fleshy mantle and the shell blister pearls are formed, such pearls are attached to shell.
2. **Baroque pearls.** These pearls are most likely to be perfectly spherical, for they are formed inside the flesh of mantle where succeeding layers of nacre may be added on all sides.
3. **Hem pearls.** These are formed near the margin of mantle where the dark pigments usually produce brown or blackish pearls.
4. **Seed pearls.** The small pearls are called seed pearls.
5. **Cultured pearls.** These are the pearls obtained from cultured species of pearls oyesters.

PEARL PRODUCING ANIMALS

Pearls are produced by bivalve molluscs. These are marine as well as fresh water:

1. The fresh water mollusc is:

Unio margaritifera.

2. The marine molluscs are:

(a) *Pinctada vulgaris*

(b) *P. fucta*

(c) *P. chemnitzi*

(d) *P. margartifera*

(e) *P. anomioides*

(f) *P. atropurpurea*

(g) *Haliotis*

(h) *Mytilus*

(i) *Placuna blacenta*

(j) *P. maxima.*

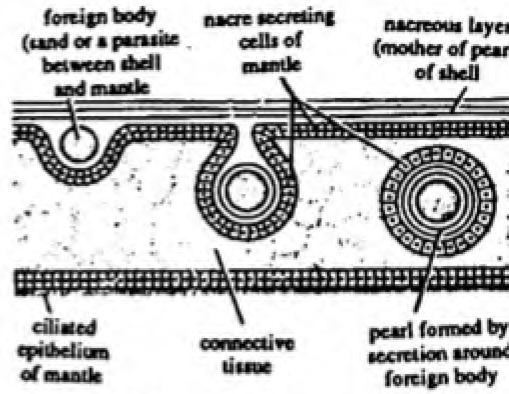


Fig. 65.1 *Pearl* formation.

The species of mollusc which is mainly is *Pinctada vulgaris.*

CULTURE OF PEARLS

The culture of pearls is a complex but sensitive process. It is involves the following steps:

1. Collection of Oysters

(i) *Japanese Method of Oyster Culture.* The larvae of the oyster freely swim in the shallow waters of the sea they are called *spats.* They are maintained in nurseries upto a certain time. For collection of spats different methods are employed. They are

(a) Semi-cylindrical tiles

(b) Bamboo poles with branches

(c) Shells of various molluscs

(d) Plastic nests

(ii) The oysters are collected from the bottom of the sea.

(iii) In the laboratories the eggs of pearl oysters are fertilized and young ones are obtained.

2. Preparation of graft tissue

The piece of tissue which is inserted into the oyster is called graft-tissue. The graft must be in the form of a square of 2 x 2 mm in size and usually it is cut off form the mantle of another oyster.

3. Preparation of nucleus

The nucleus is a foreign material which is inserted into the oyster and is in the form of a bead 2 mm in diameter.

4. Implantation

The oyster's foot is exposed and a small incision is made on the foot. On this incision the graft tissue in placed. The nucleus is placed on the graft tissue. Then the oyster is released in the cage.

5. Rearing of oysters

The operated oysters are placed in cages and are suspended in the sea from rafts. Rafts are rectangular wooden frames floating at the water surface. They are made to float by empty diesel drums. The rafts are kept in place by anchors. Besides raft other methods are there, these are long- line method, rack culture, pole culture and bottom-culture method.

6. Harvesting

Pearls attain their maximum size in three years and after the oysters are removed from cages and the pearl is taken out.

CHARACTER AND CLASSIFICATION OF ECHINODERMATA

1. Small to large animals generally found in sea water.
2. Body colour often brilliant to different shades, few are almost transppparent.
3. Body shape star-like, discoidal, circular or cylindrical with well differentiated oral-abroal surfaces.
4. Triploblastic, coelomate animal without well marked cephalization and segmentation.
5. Radial symmetrical in adult condition but the larvaa are bilaterally symmetrical.
6. The body wall is made up of three well defined layers, an outer epidermis, middle dermis and innermost peritoneum.
7. Endoskeleton in the form of calcareous, mesodermal plates and sometimes as spines hence the name echinodermata.(Gr., *echinus* = spiny; *derma* = skin).
8. An extensive body cavity or coelom surrounding the internal organs is present.
9. A part of embryonic coelom becomes modified into characteristic ambulacral or water vascular system or hydrocoel with many tube feet. This system is responsible for respiration and locomotion in animal.
10. Alimentary tract is usually coiled tube extending from the mouth located on the oral surface to the anus on the aboral or oral surface.
11. Circulatory or haemal or blood lacunar system is typically present.
12. Respiration occurs through a variety of structures, e.g. papulae in star-fishes, peristomial gills in sea urchins, genital bursae in brittle stars and cloacal respiratory trees in holothurians.
13. Excretory system is wanting.
14. Nervous ssystem is primitive, consisting of networks concentrated into the radial ganglionated nerve cords.
15. Sense organs are poorly developed.
16. Sexes are usually separate (dioecious) with few exceptions. Gonads are simple with or wothout simple ducts.
17. Reproduction is usually sexual, few reproduce asexually or by regeneration.
18. Fertilization is external, while few echinoderms are viviparous.
19. Development is indeterminate including characteristic larva which undergo metamorphosis into the radially symmetrical adults.

Phylum Echinodermata has been divided into two subphyla;

I. Subphylum - Pelmatozoa
II. Subphylum - Eleuthrozoa

SUBPHYLUM.I. PELMATOZOA

1. It includes both extinct as well as living echinoderms usually attached by a stalk i.e. sedentary.

2. Entire structure pentamerous.
3. Mouth and anus on the oral surface.
4. Tube feet are absent and the tubular ciliated appendages when prersent are without suckers.
5. Theca is differentiated into aboral cup, calyx and oral roof.
6. Arms are movable with or without pinnules.
7. Main nervous system is aboral.

Subphylum Pelmmatozoa is differentiated into 5 classes:

Class - 1. Heterostelea

1. Extinct echinoderms with laterally flatenned non-porous theca attached horizontally by a stalk.
2. Mostly without arms extensions.

Example. *Trochocystites.*

Class - 2. Blastoidea

1. Extinct echinoderms. Test bud-like, short stemmed or stemless, of 13 major plates.
2. Theca is pentamerous, radial and made up of 13 plates arranged in three rows.
3. Ambulacra five.
4. Characteristic respiratory organs, the hydrospires, situated underneath the ambulacra.

Example. *Pentremites.*

Class - 3. Cystoidea

1. Extinct animals of oval forms attached directly or by a stalk in up-right direction.
2. Theca of rigid polygonal plates, of which some are porous.
3. Ambulacra vary from 2-5.

Example: *Crystoblastus.*

Class - 4. Edrioasteroidea

1. Extinct, disc-shaped without stem or arms lying free or attached directly by the aboral surface.
2. Theca cushion-shaped with a star on top formed by five recumbent ambulacral grooves.
3. Anus and madreporite are situated on the oral surface.

Examples: *Stromatocystites, Lepidodiscus.*

Class - 5. Crinoidea

1. It includes with living as well as non-living echinoderms usually attached by a stalk, but living members are stalkless and free living.
2. Entire structure strongly pentamerous.
3. Body consists of an aboral cup, the *calyx* and oral cover or roof, the *tegmen.*
4. Oral surface directed upwards.
5. Mouth usually central, anus usually excentric are present on the oral surface..

6. Arms movable, simple, mostly branched, usually five or ten in number with or without pinnules.
7. Ambulacral groves are open and extend along arms and pinnules to their tips.
8. Madreporite, spines and pedicellariae are present.
9. Sexes are separate. Development indirect through doliolaria larva.

Class Crenoidea is divided into four orders:

Order (i) Articulata

1. Extinct as well as living forms.
2. Calyx pentamerous flexible and dicyclic.
3. Mouth and ambulaceral grooves are not covered by tegminal plates and remain exposed.
4. Tegman leathery and contains small calcareous plates or minute ossicles.

   Examples: *Metacrinus, Rhizocrinus, Antedon, Comatula.*

Order (ii) Inadunata

1. Extinct forms.
2. Calyx rigid and lower arm ossicles spring free from it.
3. Mouth covered over by tegminal plates but ambulacral grooves mostly exposed.
4. Arms three or more with or without pinnules.

   Examples: *Anartiocrimus, Hybocystites.*

Order (iii) Flexibilia

1. Extinct forms.
2. Calyx flexible, dicyclic.
3. Arms branched, devoid of pinnules and typically curved inwards.
4. Mouth and ambulacra exposed.

   Example: *Forbesiocrinus.*

Order (iv) Camerata

1. Extinct forms.
2. Calyx rigid, mono - or dicyclic.
3. Arms branched and pinnulate.
4. Mouth and ambulacra are covered.

   Example: *Xenocrinus.*

SUBPHYLUM II. ELEUTHROZOA

1. Mostly living echinoderms.
2. Stem or stalk absent, usually free-living forms.
3. Body structure usually pentameous.
4. Oral surface bearing the mouth is downward or lying on one side.

5. Anus usually on the aboral surface.
6. Ambulacral grooves usually not for food gathering and the tube feet with suckers are chiefly locomotory organs.
7. Main nervous system is oral.

Subphylum Eluthrozoa is divided into four classes.

1. Class - Asteroidea
2. Class - Ophiuroidea
3. Class - Echinoidea
4. Class - Holothuroidea

Class - 1. Asteroidea

1. Body flattened and star-shaped with a central diac and five radiating arms which are not sharply marked off from the disc.
2. Arms hollow and contain gonads, prolongation of gut, coelom and other visceral organs.
3. Ambulacral grooves open in tube feet and extend upto the tip of arms.
4. Madreporite and pedicellaria sessile.

The modern classification distinguishes class Asteroidea into two fossil and three living orders:

Order (i) Phanerozonia

1. Arms short with broad bases and with two rows of large marginal plates.
2. Papullae limited to the aboral surface.
3. Pedicellariae generally sessile or absent.
4. Tube feet with or without suckers.

Order (ii) Spinulosa

1. Arms generally without conspicuous marginal plates.
2. Pedicillariae rare.
3. Podia or tube feet are in two rows provided with suckers.
4. Aboral surface with low spines.
5. Ampullae single or bifurcated.

Examples: *Asterina, Solaster, Hymenaster.*

Order (iii) Forcipulata

1. No conspicuous marginal plates.
2. Aboral skeleton mostly reticulate with conspicuous spines.
3. Pedicillariae pedunculate and straight or crossed type.
4. Tube feet arranged in four rows provided with suckers.
5. Papulae on both surface.

Example: *Asterias, Heliaster, Brisingaster.*

Order (iv) Platyasterida

1. Extinct forms.
2. Ambulacra widely open. Arms with series of long interambulacral ossicles.

   Example: *Platasterias.*

Order (v) Hemizonida

1. Extinct forms.
2. Ambulaceral grooves are deep and ambulacral ossicles are insunk.

   Example: *Palasterina, Helianthaster.*

Class - 2. Ophiuroidea

1. Marine usually deep-sea and free living echinoderms.
2. Body flattened with a pentamerous or rounded central disc.
3. Oral and aboral surfaces are distinct.
4. Arms usually five slender, jointed, solid, muscular, flexible rarely six or seven.
5. No ambulacral grooves.
6. Pedicillariae, skill gills and special sense organs are absent.
7. Madreporite opens on the oral surface.
8. Anus and alimentary canal are absent.
9. Tube feet arising ventrolaterally from arms in 2 rows. Ampullae and suckers are absent.
10. Sexes are separate, gonads pentamerous.
11. Development includes a free-swimming pluteus larva.

Class Opiuroidea is divided into two orders:

Order (i) Ophiurae

1. Arms simple, mostly five in number, moving chiefly in transverse plane.
2. Arm ossicles articulated by pits and projections.
3. Disc and arms are usually covered with distinct shields or scales.
4. Arms spines are borne laterally and are directed outward or toward the arm tips, not downwards.
5. Single madreporite.

   Examples: *Ophioderma, Ophioscolex, Ophiothrix, Ophiocoma.*

Order (ii) Euryalae

1. Arms simple or branched.
2. Skleton of arms and disc poorly developed.
3. Arms move vertically and may be entwined around the objects.
4. It includes Brittle-stars.

   Example: *Astrophyton.*

Class - 3. Echinoidea

1. Body spherical disc-like, oval or heart shaped.
2. The body is lying enclosed in a shell formed of by closely fitting calcareous plates.
3. Outer calcareous plates are distinguished into five alternating ambulacral and five inter-ambul icral areas.
4. The oral and abroal surfaces are distinct, the mouth is located on oral surface while the anus and madreporite are present on the aboral side.
5. Tube-feet come out from the pores of ambulacral plates and are locomotory organelles.
6. Pedicillariae are stalked and three jawed.
7. Sexes separate and, glanads 5 in number and inter-radial.
8. Development includes free-swimming echinopluteus larva.

Class Echinoidea is divided in three subclasses:

SUBCLASS (A) BOTHRIOCIDAROIDA

1. A single row of plates in each inter-ambulacral area.
2. Madreporite radial.
3. Lantern of Aristotle absent.

   Example: *Bothriocidaris* (extinct).

SUBCLASS (B) REGULARIA OR ENDOCYCLICA

1. It includes globular, circular and oval forms, which are pentamerously symmetrical with two rows of inter-ambulacral plates.
2. Mouth and anus lie at opposite pole.
3. An Aristotle's lantern is present.
4. Madreporite is ambulacral.

Order (i) Lepidocentroida

1. Test flexible with overlapping or separated plates.
2. Ambulacral plates continue upto mouth lips.

   Examples: *Palaeodiscus, Sperosoma.*

Order (ii) Melonechinoida

1. Test spherical, rigid.
2. Ambulacral plates continue upto mouth lip.
3. Interambulacral plates in 4 or more rows.

   Example: *Melonechinus.*

Order (iii) Cidaroidea

1. Test rigid and globular.
2. Two rows of long narrow ambulacral plates and two rows of inter- ambulacral plates present.
3. Ambulacral and inter-ambulacral plates continue up to mouth lip.

4. Gills and sphaeridia are absent.
5. Five bushy Stewart's organs are present appended to the lantern.

   Examples: *Cidaris, Notocidaris.*

Order (iv) Centrechinoida

1. Test rigid and rarely oval.
2. Peristome with 10 buccal plates.
3. Anus surrounded by a double circle of apical plates.
4. External gills and sphaeridia present.

   Examples: *Echinus, Solenia, Diadema, Arbacia.*

SUBCLASS - (C) - IRRAGULARIA OR EXOCYCLICA

1. Bilaterally symmetrical. Test mostly flattened, oval or circular.
2. Mouth centrally placed on the oral surface.
3. Anus is displaced posteriorly generally marginal at oral or aboral surface and lies outside the apical system of plates.
4. Podia or tube feet not locomotory.

Order (i) Holectypoida

1. Test regular with simple ambulacra and centrally located peristome and apical system.
2. Ambulacra narrow on oral surface.
3. Lantern teeth with lateral flanges.

   Example: *Holectypus* (Extinct).

Order (ii) Cassiduloida

1. Aboral ambulacral area petaloid, forming a 5-armed figure.
2. Lantern absent.

   Example: *Cassidulus* (Extinct).

Order (iii) Clypeastroida

1. Test flattened, oval or rounded in shape covered with small spines.
2. Mouth and apical system are usually central and oral in position.
3. Aboral ambulacral areas petaloid.
4. Aristotle's lantern present.
5. Gills present.

   Examples: *Clypeaster, Laganum.*

Order (iv) Spatangoida

1. Test oval or heart-shaped with excentric mouth and anus.
2. Four aboral ambulacral areas petaloid, fifth not petaloid.
3. Lantern absent.

4. Gills absent.

   Examples: *Spatangus, Lovenia, Hemiaster.*

Class - 4. Holothuroidea

1. Body bilaterally symmetrical, usually enlongated in the oral- aboral axis having mouth at near one end and anus at or near the other end.
2. Endoskeleton reduced to microscopic spicules or plates embedded in the body wall.
3. Mouth surrounded by a set of tentacles attached to water vascular system.
4. Podia or tube feet are usually present and locomotory.
5. Alimentary canal is long and coiled and cloaca usually with respiratory trees.
6. Sexes are usually separate and gonad single or made of one or two tufts of tubules.
7. Development may be direct or indirect with a larva called auricularia.

Order (i) Aspidochirota

1. Podia or tube feet numerous.
2. Mouth is surrounded by 10-30 mostly 20 peltate or branched oral tentacles.
3. Retractor muscles of pharynx absent.
4. A pair of well developed respiratory trees is present.

   Examples: *Holothuria, Stichopus, Mesothuria.*

Order (ii) Dendrochirota

1. Holothurians with numerous podia.
2. Oral tentacles dendroid.
3. Retractor muscles and respiratory tree present.
4. Madreporite internal.

   Examples: *Cucumaria, Thyone.*

Order (iii) Elasipoda

1. Oral tentacles 10-20, peltate or shield shaped.
2. Tentacular ampullae, oral retractors and respiratory trees are absent.
3. Madreporite may be internal or external.
4. Body generally flat ventrally, with mouth usually ventral.
5. Tube feet few.

   Examples: *Elpidia, Pelagothuria.*

Order (iv) Malpadonia

1. Oral tentacles unbranched and digitate or with minute branches at the tip.
2. Madreporite internal and respiratory tree present.
3. Tube feet absent and posterior end of body tapers to form caudal region.

Examples: *Malpodia, Caudina.*

Order (v) Synaptida or Apoda

1. Body vermiform having smooth or warty surface.
2. Podia or tube feet absent.
3. Oral tentacles are 10-20. Simple, digitate or pinnate.
4. Pharyngeal retractors are present in some forms.
5. Respiratory trees are absent.
6. Water vascular system greatly reduced.

Examples: *Synapta, Chiridota.*

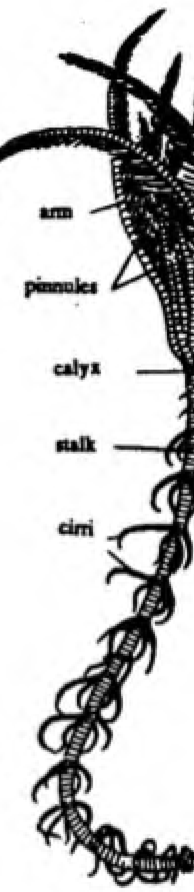


Fig. 66.1 *Metacrinus.*

METACRINUS

Phylum	-	Echinodermata
Subphylum	-	Pelmatozoa
Class	-	Crinoidea
Order	-	Articulata
Genus	-	*Metacrinus*

1. It is commonly known as 'sea-lily'.
2. It is a marine animal found at moderate depths. It is found in Japan, Malaya and Australian region.
3. The calyx is small and appears to be monocyclic.
4. It has four branchials between the radials and first branching.
5. The five arms are long, each dichotomouldy divided three times and with small uniserial pinnules.
6. Stalk is long, distinctly pentamerous and jointed.
7. Around the joints are present whorls of numerous slender, many jointed cirri, which are used for temporary attachment.

CTENODISCUS

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Asteroidea
Order	-	Phanerozonia
Genus	-	*Ctenodiscus*

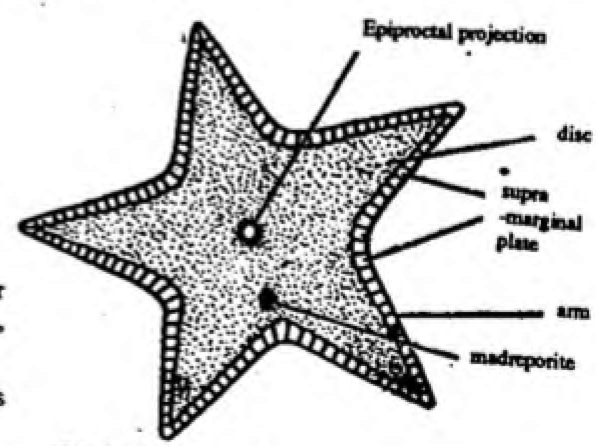


Fig. 66.2 *Ctenodiscus.*

1. It is commonly known as 'mud-star' found in a shallow water circumpolar type ranging from cold northern waters to California, Japan and Cape cod.
2. Body form varies from pentagonal to stellate with conspicuous marginal plates without spines.
3. The aboral wall is thin, membranous and covered by paxillae and a tube-like epiproctal projection arises from its centre.

4. Between certain adjacent marginal plates occur vertical rows of thin folds of integument, called cribiform organ.

5. Intestine, intestinal caeca and anus are lacking.

LUIDIA

The systematic position is the same as that of *Ctenodisacus.*

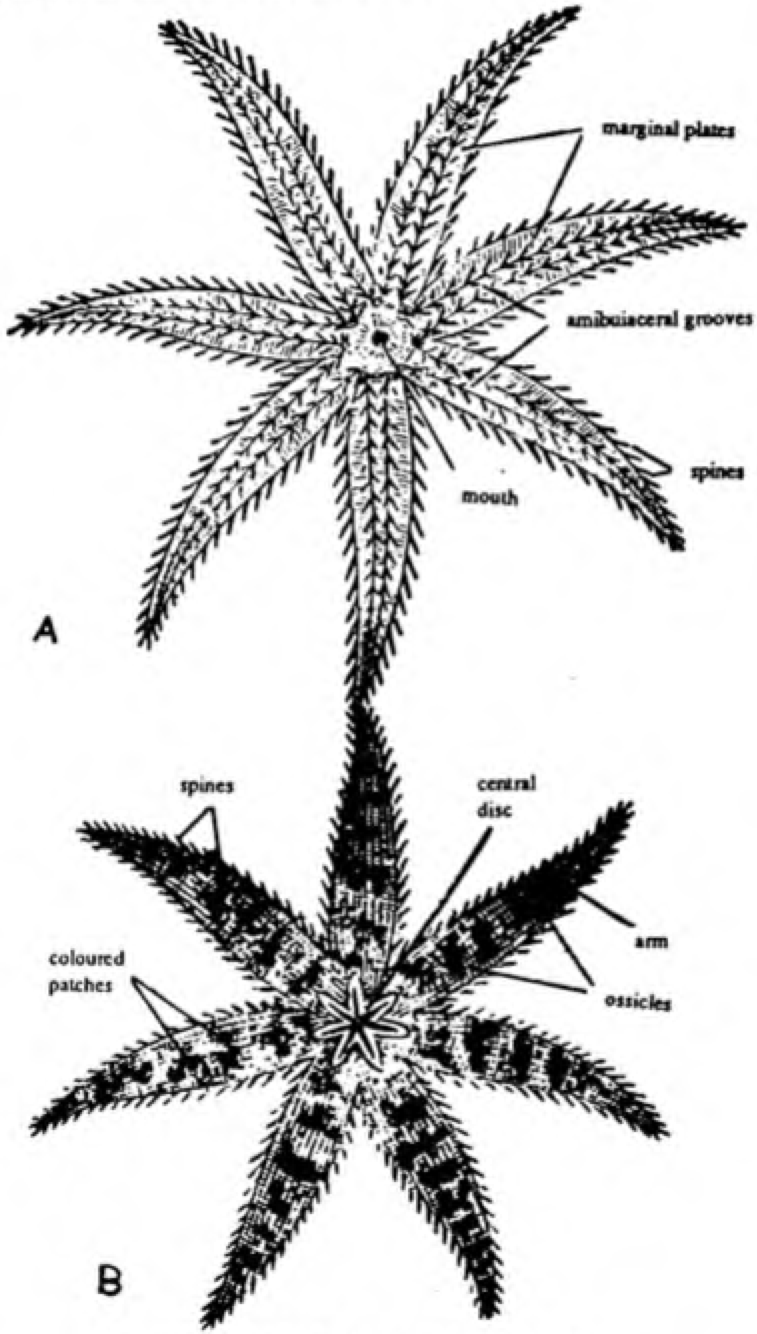


Fig. 66.3 *Luidia.* A—Oral view, B—Aboral view.

1. It is a littoral form, found in tropical and subtropical seas.
2. Disc is comparatively small and arms are long and flexible.
3. Arms may vary from 5-11 and are bordered with spines.
4. Body is differentiated into oral and aboral surfaces.
5. The oral surface contains a central mouth which communicates with ambulacral groove in each arm.
6. Inframarginal plate is separated from the ambulacral plate by a small intermediate plate.
7. Aboral surface is covered by several small rectangular ossicles and is marked by coloured patches.
8. Anus and intestinal caeca are absent.
9. Pedicillariae are present.
10. Gills are branched.
11. Each ambulacral groove accomodates two rows of tube-feet.
12. A polynoid polychaete (*Achloe astericola*) is found as commensal in the ambulacral groove of *Luidia*.

ASTROPECTEN

The systematic position is same as that of *Ctenodiscus*.

1. It is a large star-fish, commonly found in sea below the tide line to great depths.
2. It is found in all parts of world namely New Jersey southwards, and California.
3. Body flattened, star shaped with five long slender arms radiating from central disc.
4. Oral and aboral surfaces are distinctly marked.
5. The oral surface contains centrally placed mouth which communicates with 5 broadly opened ambulacral grooves having double rows of tube feet.
6. Tube feet without suckers.
7. The aboral surface has madreporite in one of its interradii.
8. Anus and pedicillariae absent.
9. The stone canal is extremely complicated due to internal development of ridge.
10. The optic cushion contains retinal cells.
11. Sexes are separate. The development includes *brachiolaria larva*.

Fig. 66.4 *Astropecten.*

OREASTER (PENTACEROS)

The systematic position is the same as that of *Ctenodiscus.*

1. It is most common starfish found in sea from shallow water to 1000 fathoms.
2. It is found in U.S.A., U.K., India and South America.
3. It is commonly called 'sea pentagon'.
4. Body is enclosed in hard leathery integument which contains.

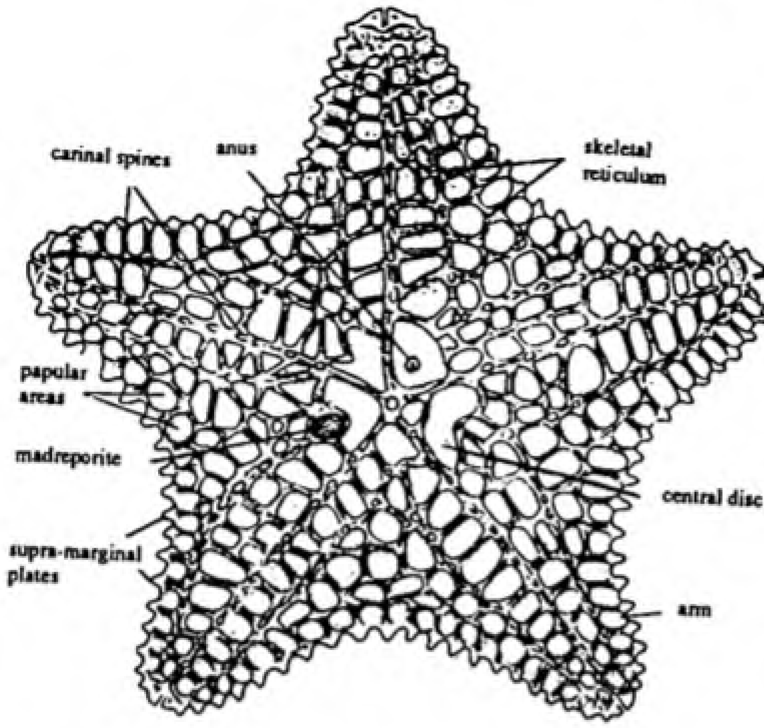


Fig. 66.5 *Oreastes (Pentaceros).*

5. Central disc and arms are fused together.
6. Arms are five in number and arranged around a central disc in the form of star.
7. Body surface can be differentiated into oral and aboral surface.
8. Aboral surface is convex and brown in colour.
9. Oral surface is concave and dark brown in colour.
10. Mouth is present on the oral surface and is five angles and each angle is continued into the ambulacral groove up to the tip of an arm.
11. Madreporite plate is present in one of the inter-radii. It forms the first part of water vascular system.
12. The ambulacral grooves contain double row of locomotory organs or tube-feet.
13. Sexes are separate. Development is indirect through a *bipinnaria larva.*

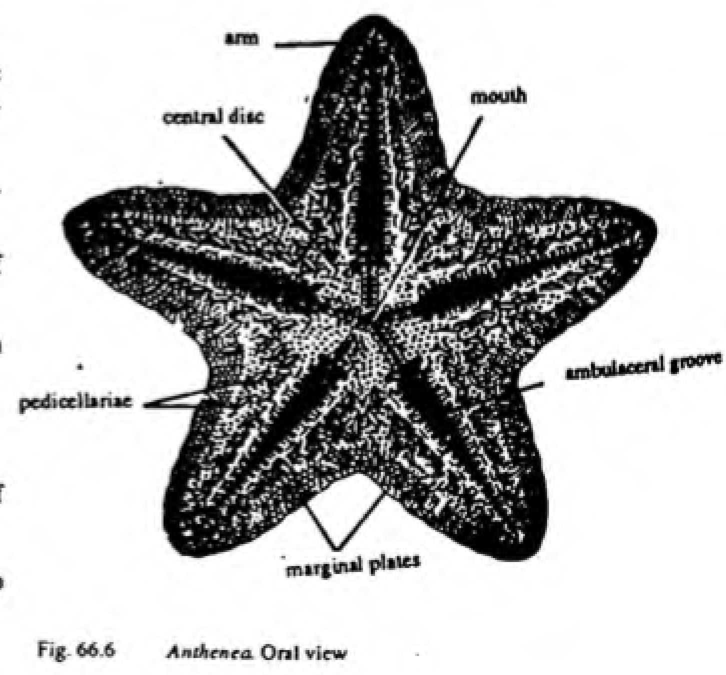


Fig. 66.6 *Anthenea.* Oral view

ANTHENEA

The systematic position is the same as that of *Ctenodiscus.*

1. It is found in all the seas from shallow to deep waters.
2. It is most common in Australian sea.

3. Body consists of relatively large central disc and five relatively short arms.
4. Body is differentiated into oral and aboral surfaces.
5. Aboral surface is convex, having interradial depression.
6. The oral surface is broad and flat containing a central mouth and five ambulacral grooves.
7. The flat surface between the ambulacral groove contains plate-like ossicles beset with a number of minute rounded tubercles and granules which some time assume the shape of spine.
8. Pedicillariae present on both the surfaces.
9. It possesses vertical calcareous and inter-radial partitions.

SOLASTER

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Asteroidea
Order	-	Spinuloa
Genus	-	*Solaster*

1. It is found in Northern waters.
2. Body has 9-14 arms with two rows of marginal plates.
3. The aboral skeleton is reticulate, the plates forming a fine network with small meshes and carrying on a projecting tubercle, a crowded bundle of spinelets.
4. Pedicillariae are absent.
5. Carnivorous, feed on other echinoderms, particularly asteroids.
6. Anus is distinct.

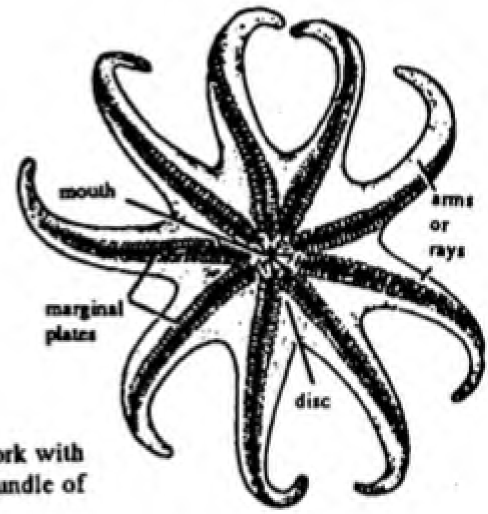


Fig. 66.7 *Solaster.*

HELIASTER

Phylum	-	Echimodermata
Subphylum	-	Eleutherozoa
Class	-	Asteroidea
Order	-	Forcipulata
Genus	-	*Heliaster*

1. It is found in shallow waters in panamic region.
2. It has a broad disc with 40 or more short, tapering arms.
3. Skeleton is reticulate having both straight and crossed pedicillariae.
4. Madreporite is present.
5. Tube-feet arise in four rows.
6. Interbranchial septa are double.
7. It begins its life with five rays, but additional rays are added in inter-radii except that which contains the madreporite.

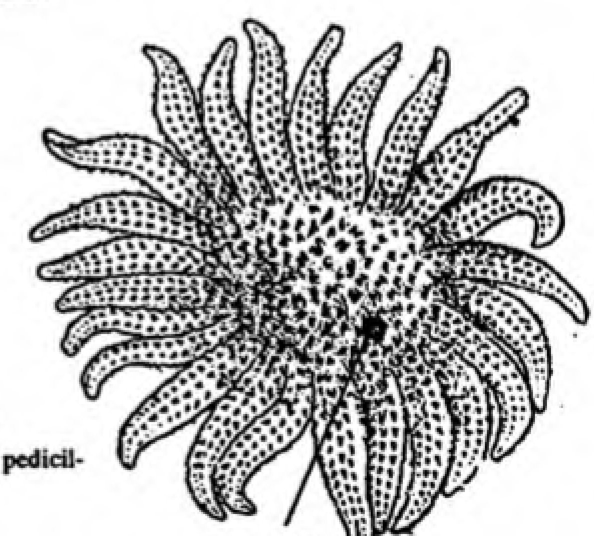


Fig. 66.8 *Heliaster.*

OPHIODERMA

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Ophiuroidea
Order	-	Zygophiural
Genus	-	*Ophioderma*

1. *Ophioderma* is a brittle star of littoral zone tropical West Indian seas.
2. Found along the North Atlantic Mediterranean, littoral, tropical and West Indian seas.
3. Body with prominent pentagonal disc of brownish colour having five arms which are sharply distinct from disc and freely movable upon central disc.
4. Arms are slender, jointed, solid, cylindrical, muscular and flexible.
5. Disc coated with granules.
6. Mouth fringed with numerous oral papillae.
7. Dental papillal are absent and teeth are arranged in a single row.
8. There are four bursal slits in each interradius, two located orally and two peripherally.
9. The spines of arms are very small so that the arms are smooth.
10. Sexes are separate. Development with free-swimming *pluteus larva*.

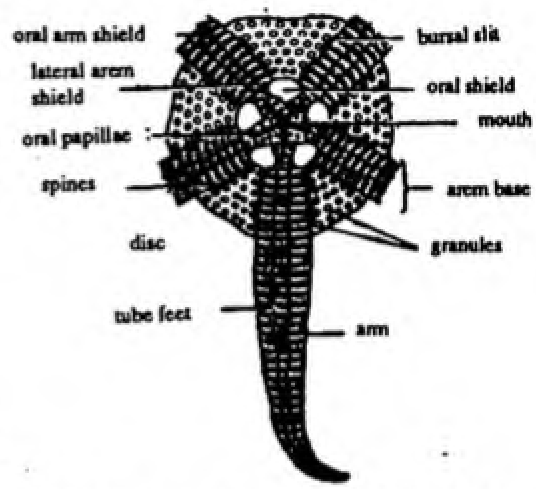


Fig. 66.9 *Ophioderma.* Disc and one arm in oral view.

OPHIOGLYPHA OR OPHIURA

The systematic position is the same as that of *Ophioderma.*

1. *Ophioglypha* is a cosmopolitan brittle star found in almost all sea water.
2. It has cosmopolitan distribution.
3. Body with flat, pentagonal, central disc, covered with radial shields and numerous small scales.
4. Arms are five and markedly set off from central disc, which are of moderate length and covered with regular plates.
5. The arm plates of lateral side have closely lying spines.
6. Buccal podia of second pair open not into the mouth angles but on the oral surface.
7. Arms combs are present.
8. Bursal slits are two in each inter-radius.
9. The prey is caught by coiling around the arms.
10. Male and female are separate development indirect with *ophiopluteus larva.*

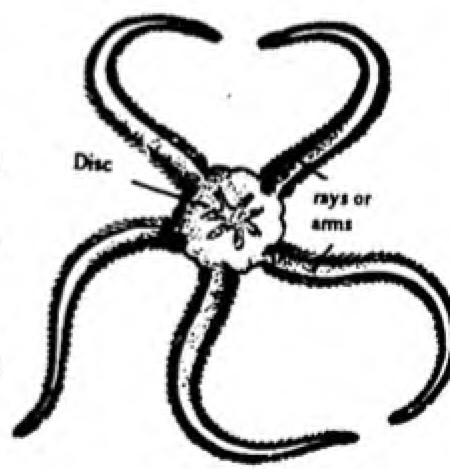


Fig. 66.10 *Ophioglypha.*

OPHIOCOMA

The systematic position of *Ophiocoma* is same as that of *Ophioderma.*

1. It is commonly called 'brittle star'. It is commonly found in shallow waters.
2. It is found along the Red Sea shores, West Indian region and Florida.
3. Body consists of a small rounded central disc and five long, slender tapering arms.
4. Oral and aboral surfaces are well marked.
5. Mouth is pentagonal situated in the centre. Madreporite is present in one of the inter-radial areas.

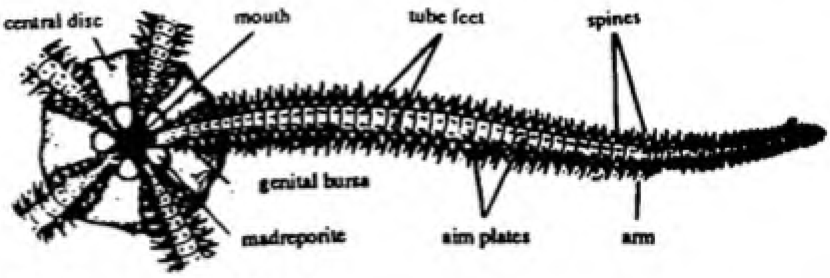


Fig. 66.11 *Ophiocoma*. Oral view.

6. The oral surface has leathery skin.
7. Anus and pedicillarial absent.
8. The ambulacral grooves covered.
9. There are 10 elongated slits, two an either side of the base of each arm called as *genital bursae* in which gonoducts open.
10. Three rows of pointed spines are borne on the lateral plates. A row of short tube feet project on each side between lateral and lower plates.
11. The tube feet are devoid of suckers they are only respiratory and sensory.

ASTROPHYTON

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Ophiuroidea
Genus	-	*Astrophyton*

1. It is commonly known as 'basket star'.
2. It is found in deep sea often rotting on sea bottom.
3. Body surface is soft and devoid of spines.
4. Pentagonal disc is very large and circular.
5. Aboral surface bears spoke-like radial shields which radiate from the centre to the periphery.
6. Fine arms are long, slender and repeatedly branched with tendrillar tip which assist in clinging the objects.
7. One madreporite is present in each inter-radius.
8. Development occurs passing through *ohiopluteus larva*.

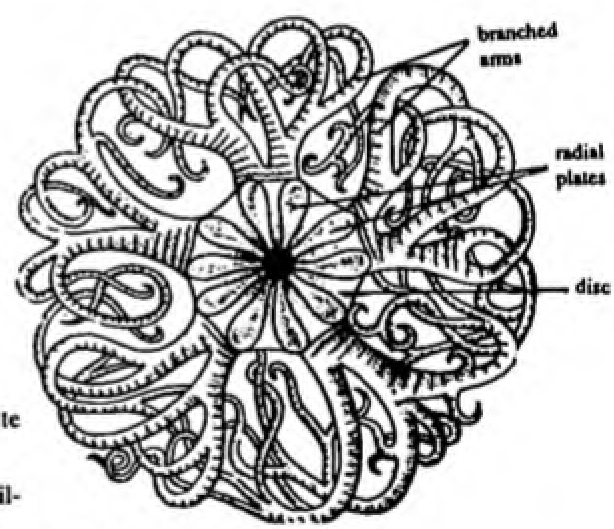


Fig. 66.12 *Astrophyton*.

GORGONOCEPHALUS

The systematic position is the same as that of *Astrophyton*.

1. It is another deep sea water echinoderm and commonly called 'basket star'.
2. The disc is either pentagonal or circular and large.
3. The aboral surface of disc shows long and spoke-like radial shields, radiating from the centre of the disc to the margin.
4. Disc margin between the radial shields bear a series of plates.

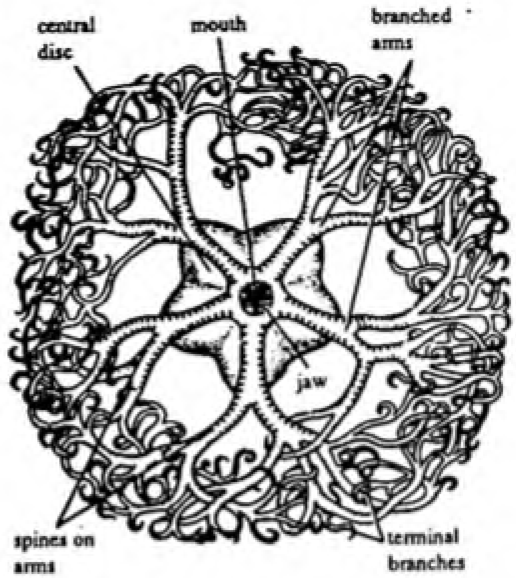


Fig. 66.13 *Gorganocephalus*. Oral view.

5. The five arms are long, slender and flexible and repeatedly branching dichotomously.
6. One medreporite is present is each inter-radius.
7. Bursal slits are short and fusion of bursae from large spaces so that true coelom is greatly reduced.
8. Development occurs through *ophiopluteus larva*.

CLYPEASTER

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Echinoidea
Subclass	-	Irregularia
Order	-	Clypeastroida
Genus	-	*Clypeaster*

1. It is found on or buries in sandy bottoms of tropical and subtropical seas.
2. It is commonly called as 'cake-urchin'.
3. The corona is depressed and disc-shaped, covered all over with short stiff and dark brown spines. Differentiated into oral and aboral surfaces.
4. Oral surface flat and covered with a dense velvet of short and stiff spined and differentiates into five petaloid ambulacral areas and five interambulacral areas.
5. Aboral surface slightly convex and anus is present eccentrally.

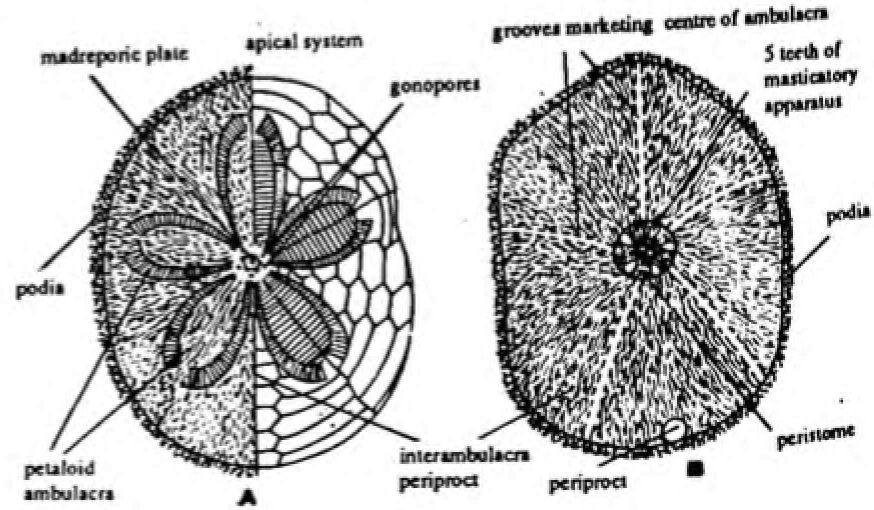


Fig. 66.14 *Clypeaster*. A—Aboral view, B.—Oral view.

6. Madreporite is centrally placed and form a radiate five wide, well-marked petaloid ambulacral areas.
7. Tube feet on the aboral ambulacral areas are flatenned and respiratory.
8. Arms and ambulacral grooves are absent.
9. Pedicillariae are present.
10. Aristotle's lantern with teeth developed which is of simple type.
11. Genital plates are fused with the central pentagonal plate. Radial oscular plates are distinct.
12. Development includes *echinopluteus* larva.

ECHINARACHINUS

The systematic position is the same as that of *Clypeaster*.

1. It is commonly found about 800 fathoms deep, lying on sand or partly buried.
2. It is found along W. Coast of North America, Pacific Coast and U.S.A.
3. It is commonly called 'sand dollar'.
4. Body is greatly flatenned in the oral-aboral direction and covered with soft fur of delicate spines.
5. The oral surface is composed of interlocking ambulacral and interambulacral ossicles beset with tiny spines.
6. Mouth centrally situated, surrounded by five petaloid ambulacra. Ambulacra representing opening for tube feet in double row.
7. Madreporite plate, ocular plate and genital plate with genital opening are found on aboral surface.
8. Anus is present on aboral surface.
9. Development includes *echinopluteus* larva.

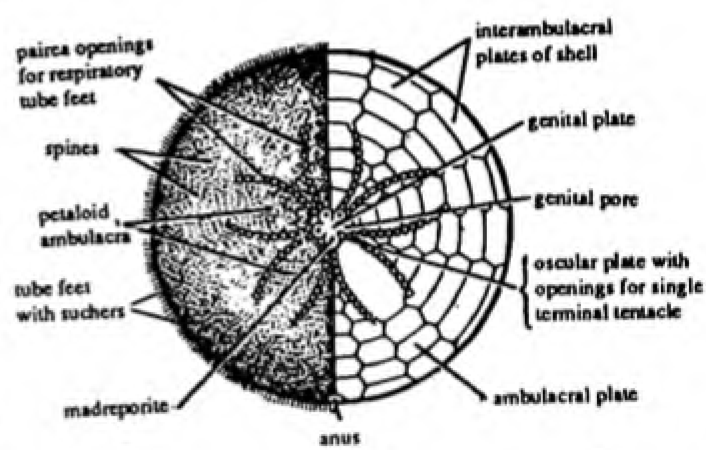


Fig. 66.15 *Echinarchinus.*

ECHINOCARDIUM

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Echinoidea
Subclass	-	Irregularia
Order	-	Spatangoida
Genus	-	*Echinocardium*

1. It burrows in sand. It has world wide distribution.
2. It is commonly called 'heart-urchin', as the shape resembles a heart.
3. Body outline cardiform generally light brown in colour.
4. Four petaloids well formed which are flush with test.
5. Mouth eccentric, lies near the anterior end with transver-

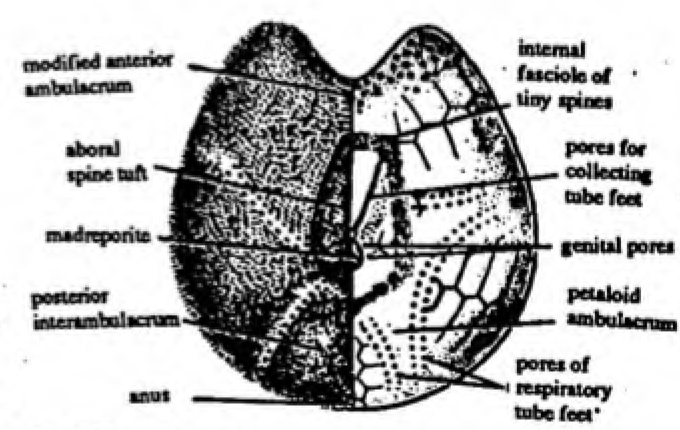


Fig. 66.16 *Echinocardium.*

sely elongated peristome.

6. Anus situated at the posterior end with periproct.
7. Ambulacra five, petaloid and aborally situated.
8. The Aristotle's lantern is absent.
9. Pedicillariae are of two types with only 2 jaws and scattered among the spines. Poison pedicillariae are absent.

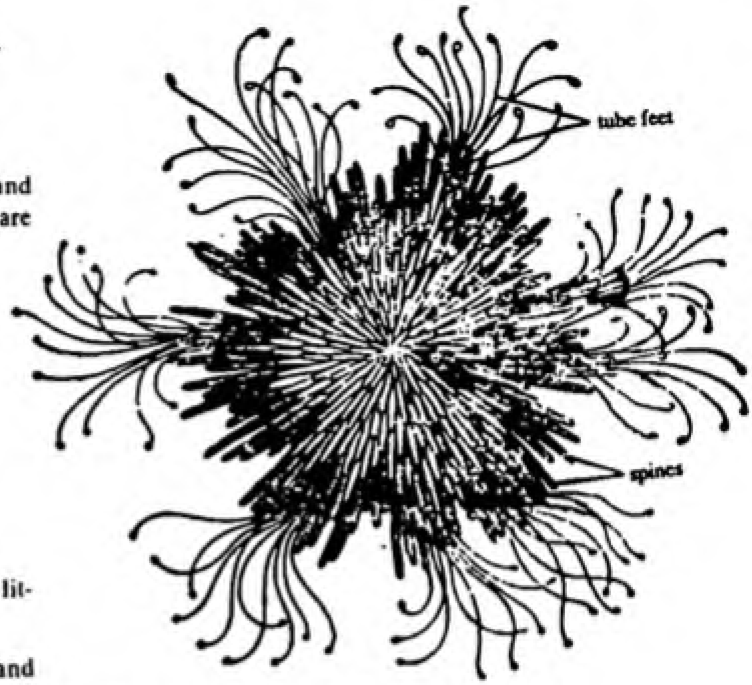


Fig. 66.17 *Strongylocentrotus.*

STRONGYLOCENTROTUS

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Echinoidea
Subclass	-	Regularia
Order	-	Camarodonta
Genus	-	*Strongylocentrotus*

1. It is commonly called as 'sea-urchin', found in littoral sea.
2. Body is slender in out line and bears slender and short spines.
3. Mouth and anus lie at opposite poles.
4. Body is differentiated into ambulacral and inter-ambulacral areas.
5. Each ambulacral plate bears 7-10 pairs of pores.
6. Tube-feet are arranged in five double rows and are greatly extensible.
7. Tubercles are unequal in size and arranged in numerous series and often crowded.
8. Pedicellariae are gemmiform.
9. Gill-clefts are shallow.

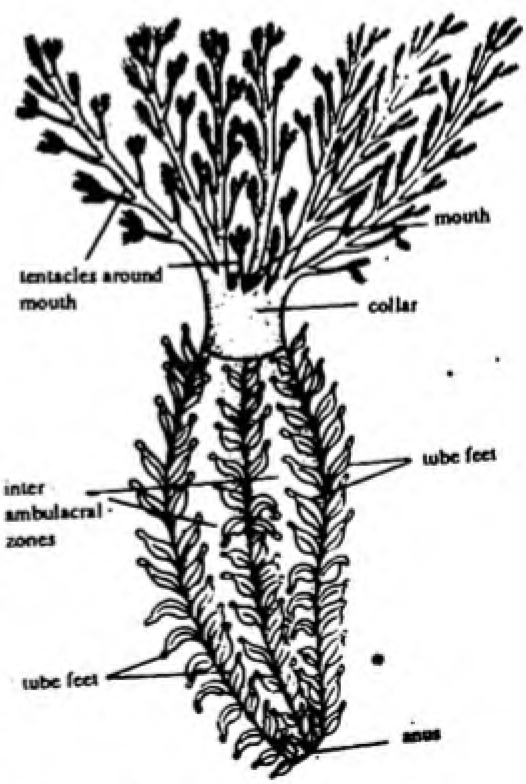


Fig. 66.18 *Cumcumaria.*

CUCUMARIA

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Holothuroidea
Order	-	Dendrochirota
Genus	-	*Cucumaria*

1. *Cucumaria* is a very common sea cucumber, benethonic and sluggish in habits.
2. Generally feeds on small organisms. Cosmopolitan in distribution and specially found in Europe, U.S.A. and India.
3. Body is cucumber-like and is generally cylindrical.
4. Mouth is at broad oral end and the anus at the aboral end which is somewhat narrow.
5. Body is pentamerous, having five longitudinal bands or ambulacra,

each provides with locomotory podia.

6. Mouth is surrounded by a lip and peristomial membrane having circular row often dendritic or tree-like tentacles.
7. This collar-like region at the base of tentacles is known as introvert.
8. The genital aperture is situated mid-dorsally in between the bases of two adjacent bivial ambualacral tentacles.
9. Body without spines and pedicellariae but highly muscular, leathery and slimy.
10. The exoskeleton in the form calcareous spicules.
11. Sexes are separate.
12. Development with auricularia larval stage.

THYONE

The systematic position is the same as that of *Cucumaria*.

1. It is free swimming holothurian generally found burried in muddy and sandy bottoms of sea.
2. It is found in U.S.A.
3. Podia or tube feet are distributed over the entire body surface.
4. Mouth is at the oral end and surrounded by introvert and ten dendritic tentacles which can be extended to great length.
5. Two tentacles attached to the mid-ventral ambulacral area, are much smaller than others.
6. Anus is present on aboral end.
7. *Thyone* is famous for its great power of regeneration and autonomy.
8. Sexes are separate.
9. Development indirect with *auricularia* larva.

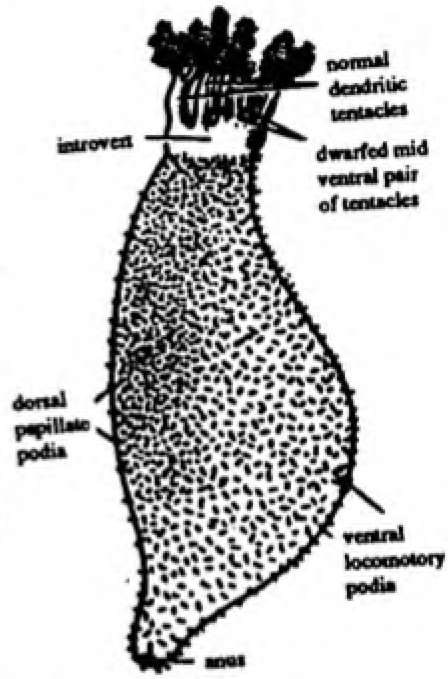


Fig. 66.19 *Thynoe.*

ACTINOPYGA

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Holothuroidea
Order	-	Aspidochirota
Genus	-	*Actinopyga*

1. It is found in all the sea waters and commonly called sea cucumber.
2. Body is large cylindricle.
3. The entire ventral creeping sole is crowded with numerous locomotory tube-feet.
4. The warts covering the dorsal surface also lack any definite arrangement.
5. The anus is placed at the extreme aboral end. Five calcareous teeth are present within the rim of anus.
6. From the base of left respiratory tree arise a few or

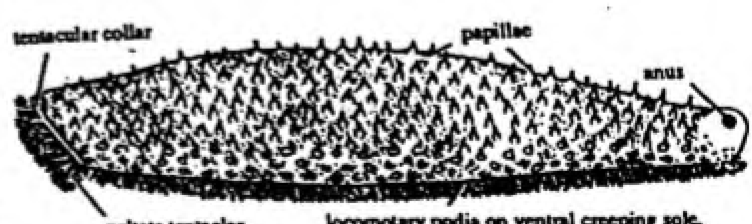


Fig. 66.20 *Actinopyga.*

numerous pink *Cuvierian tubules* which are emitted from anus, when stimulated.

7. The tubules are toxic to fishes and other animals.

SYNAPTA

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Holothuroidea
Order	-	Apoda
Genus	-	*Synapta*

1. *Synapta* is generally found completely burried in soft, sandy soil of the sea bottom.
2. Found in Europe, Pacific coast and Bermuda.
3. Body is elongated, vermiform with rough or warty surface.
4. Tube feet are absent.
5. Mouth is surrounded by 15 short, digitate tentacles.
6. Anus situated at the aboral end.
7. Respiratory tree and Cuvierian organ absent.
8. Exoskeleton of calcareous spicules are completely absent but with arches and anchor plates.
9. Hermaphrodite. Gonads consist of one pair of branching tubules.
10. Development indirect.

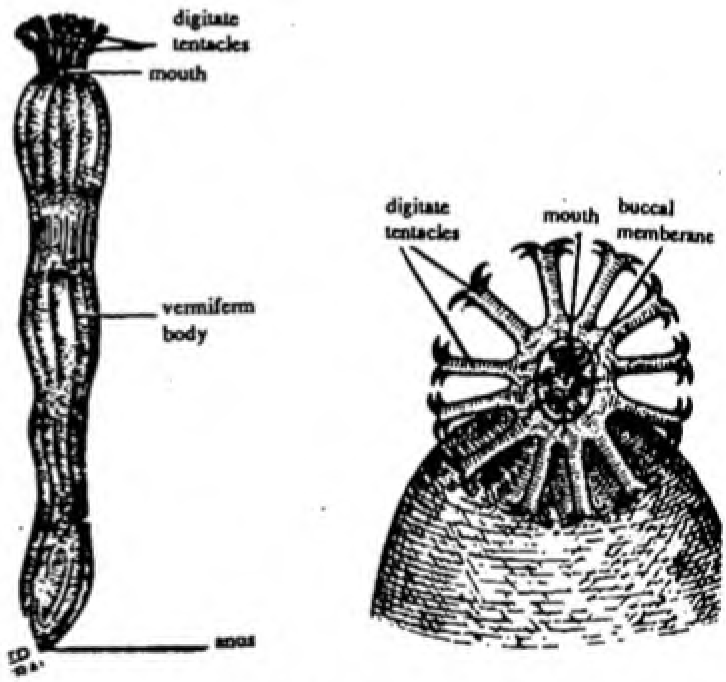


Fig. 66.21 *Synapta*. A—Entire, B—Oral.

67

ASTERIAS

Asterias is commonly called as 'starfish'. The name starfish is somewhat misleading suggesting an organism to be star-like and fish but it lacks in both the characters. However, it is appropriate to call it as sea-star as it is star-like in shape and occurs in sea. The genues *Asterias* includes about 150 species.

SYSTEMATIC POSITION

Phylum	-	Echinodermata
Subphylum	-	Eleutherozoa
Class	-	Asteroidea
Order	-	Forcipulata
Genus	-	*Asterias*

DISTRIBUTION

There are about 1000 species of sea stars and genus *Asterias* includes about 150 species. They have different geographical distribution *Asterias rubens* occurs on the English and North European coasts, *A. vulgaris* on the North Atlantic coast of N. America, *A. forbesi* on the eastern shore from the Maine to the Gulf of Mexico, *A. amurensis* from the Behring sea, Japan, Korea Northward and *A. tenera* occurs on the sea shore from North Scotia to New Jersey.

HABITS AND HABITAT

Asterias are free-living and marine echinoderms, crawling about slowly in shallow water to very great depths. It prefers rocky areas where locomotion and concealment are easier. However, the species that live more or less buried necessarily occur on the sandy bottom. The bottom living animals are known as benthonis. The most species of *Asterias* are generally solitary but many individuals gather at some place for protection from the direct rays of sun and from excessive drying. Most of them are nocturnal, remain quiet in day time and become active during night. It creeps slowly along the sea bottom. In spite of having a hard integument, it can bend and twist in a variety of ways. They are carnivorous and feed voraciously. They exhibit remarkable power of autotomy and regeneration.

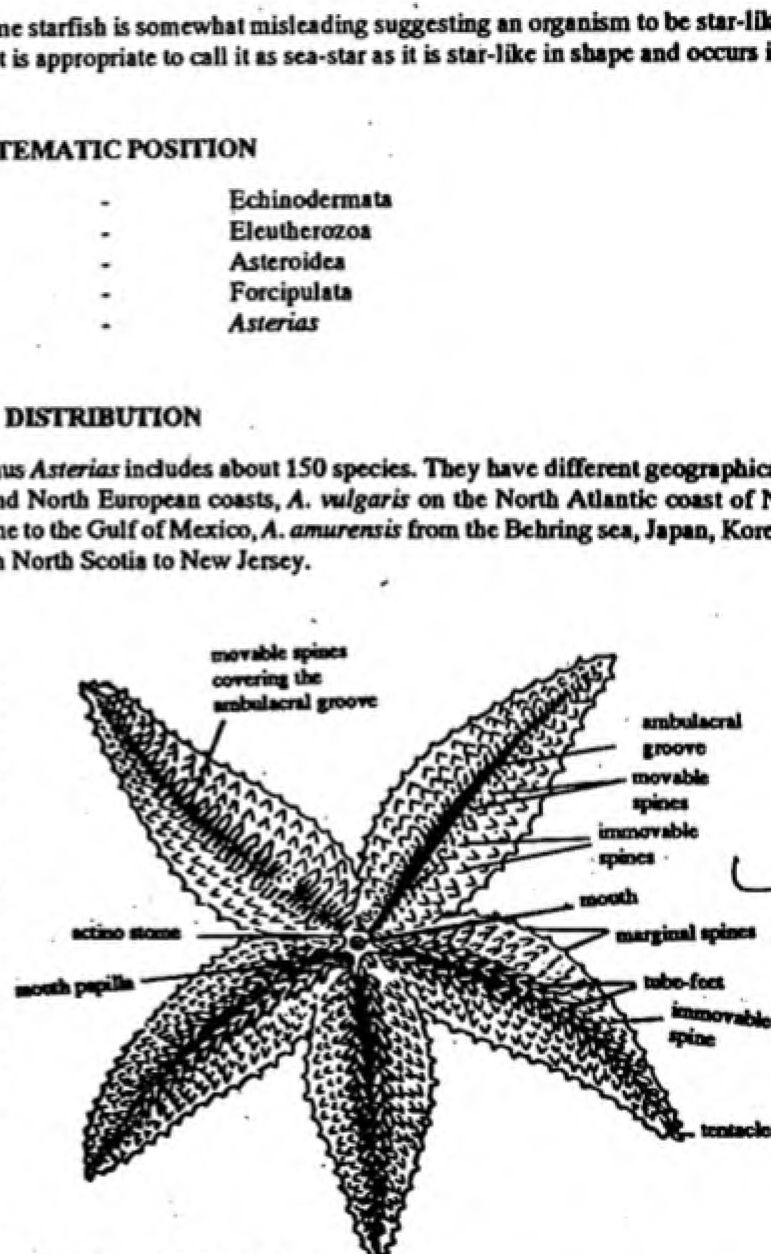


Fig. 67.1 *Asterias*. Oral view.

EXTERNAL MORPHOLOGY

Shape, Size and Colouration. The body is flattened in oral-aboral axis and is generally pentamerous

in arrangement. The body consists of a central, pentagonal central disc from which radiate out five elongated, tapering, symmetrical spaced rays or arms. 6, 7 or 8 rayed specimens are rare and probably result due to regeneration after injury. The body has two distinct surfaces, oral and aboral. The oral surface is flat, directed down wards having a centrally placed mouth. The aboral surface is convex, directed upwards and much darker in colour. The oral and aboral surfaces are not the ventral and dorsal surfaces but correspond to the left and right sides of the bilaterally symmetrical larva. The axes occupied by the arms are known as radii and the regions of the central disc between the arms are interradi. A well defined head is entirely absent.

The size varies from 10-20 cm in diameter. The smallest sea-star known is about 1 cm in diameter and the largest 80 inches.

They are usually brightly coloured yellow, brown or orange and purple. The colouration is due to carotenoid pigments.

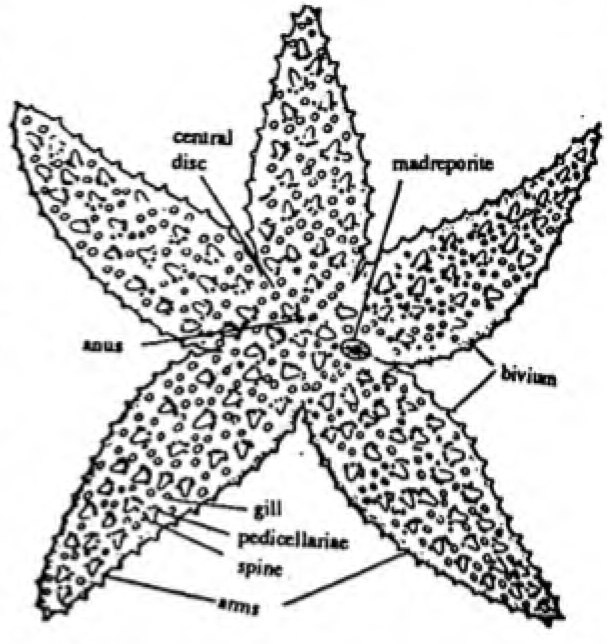


Fig. 67.2 *Asterias.* Aboral view.

Oral or Actinal surface

It is the lower flat surface of the body which bears a mouth and usually applied to the substratum. It bears following structures:

1. *Mouth.* On the oral surface, in the centre of the pentagonal central disc is an aperture, the actinosome or mouth. It is a pentagonal aperture with five angles, each directed towards an arm. The mouth is surrounded by a soft and delicate membrane, the peristomial membrane or peristome and is guarded by five groups of oral spines or mouth papillae.
2. *Ambulacral grooves.* Ambulacral grooves radiate out from the five corners of the actionostome and extend one to each arm along its middle upto the distal end. Each groove is bordered by two rows of calcareous ambulacral spines. Their bases have muscles, which can bring about the movement of the spines overlapping the tube feet to protect them from injury. External to the ambulacral spine are three rows of large stout immovable spines.
3. *Tube feet.* The tube feet are soft, extensile, tubular processes arranged in 4 radial rows in each ambulacral groove. Each tube foot is provided with terminal disc or sucker. The sucker works as suction cup to afford a firm attachment on the surface to which it is applied. These are multipurpose organs as they help in locomotion, food capturing, respiration and as a sensory organs.

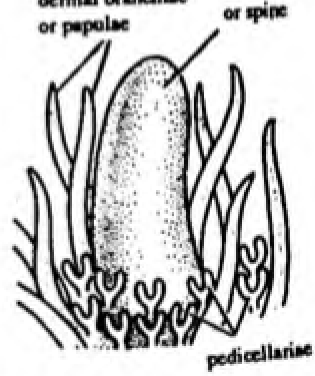


Fig. 67.3 *Asterias.* A small area of body surface highly magnified.

4. *Ambulacral spines.* The spines are present in a definite arrangement. Each ambulacral groove is boardered and guarded laterally by 2 or 3 rows of movable calcareous adambulacral spines. They can be brought together to form a lattice-work over the tube feet retracted into the ambulacral groove. At each angle of mouth, these spines become larger, stouter and grouped together to form a mouth papilla. Outside the admbulacral spines are three rows of immovable spines. There is a row of similar spines along the borders of the arms demarcating the oral from aboral surface.
5. *Sense organs.* These include five unpaired tentacles and five eye spots. The tip of each arm bears a small median non-retractile and sucker-less terminal tentacle. It acts as a tectile and olfactory organ. At the base of each tentacle, there is a small, light sensitive, bright-red spot called the eye. It is made up of several ocelli.

Aboral or abactinal Surface

The aboral side remains directed upward and usually it is orange or purplish in colour. It bears following structures:

1. *Anus.* It is a small aperture hardly visible with the naked eye. It is situated very nearly, though not exactly, in the centre of the aboral surface, in an interradius next to that occupied by the madreporite.

2. *Madreporite.* The aboral surface is marked by the presence of an asymmetrical subcircular plate known as madreporite. It is present in the central disc in one of the interradii close to the base of two arms. The two rays between which the madreporiate is placed are termed the *bivium*, remaining three are called *trivium*. Madreporite introduces bilateral symmetry, because it is only through one vertical plane, which passes through the middle of the madreporite as well as the middle of the opposite arm, that the *Asterias* can be divided into two equal, right and left, halves. The surface of madreporite bears a number of radiating, narrow straight or wavy grooves with pores in them.

3. *Spines.* The entire aboral surface is also covered with stout, blunt calcareous spines or tubercles. They arise from the calcareous plate or ossicles. The ossicles are embedded in the body wall and covered by epidermis forming the endoskeleton. The spines are arranged in irregular rows parallel with the long axis of the rays.

4. *Dermal branchiae.* The dermal branchiae or gills or papulae are very small, delicate, tubular or conical, finger-like or thread-like, thin walled processes protruding through minute pores in the integument between the ossicles on the aboral surface. The papulae are hollow evaginations of the body wall and their lumen remain in continuation with the coelom. Internally they are lined with coelomic epithelium. They can be completely retracted into the body. They have respiratory as well as excretory functions.

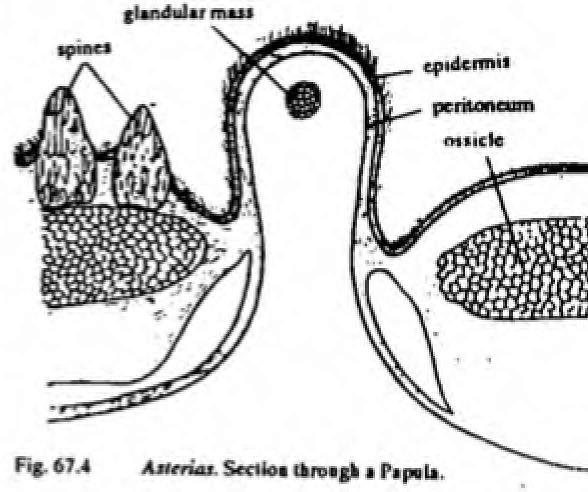


Fig. 67.4 *Asterias.* Section through a Papula.

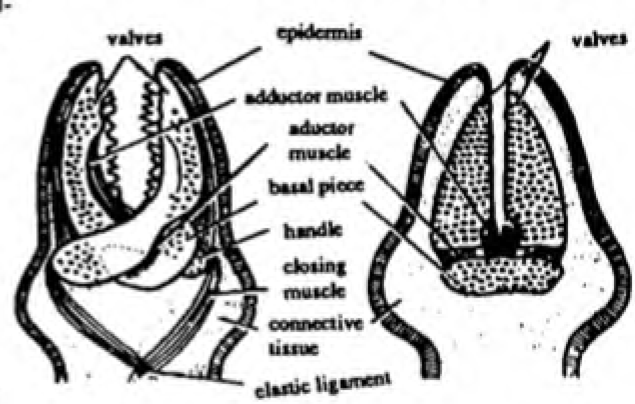


Fig. 67.5 *Asterias.* Pedicillarias crossed and straight types.

Pedicillariae. These structures are present scattered all over the body. These are found in the intervals between the spines of the aboral surface. But, on the oral surface, they are attached to the bases of spines and also in the spaces between them.

These are small whitish, jaw-like or pincer-like structures. They may be stalked or sessile. In *Asterias* only stalked types of pedicillariae are found. Each pedicillaria has a short, flexible and fleshy stalk, lacking internal calcareous support. It possessess two articulating calcareous blades or valves which are supported and articulated by a third calcareous plates is called basilar or basal piece. This type of pedicillaria, which is made up of three plates is called *forcipulate.* The opposite surfaces of the blades or valves are serrated and their opening and closing is controlled by one pair of abductor and two pairs of adductor muscles respectively.

Asterias Possesses two types of Pedicillariae:

(i) Straight type or Forceps type. The two jaws are more or less straight and attached basally to the basal piece. When closed they remain parallel and meet throughout their length like a forceps. These are closed by adductor muscles and open by abductor muscles.

(ii) Crossed type or Scissors type. The basal ends of two jaws cross each other as scissors, so that the basal piece is enclosed between their crossed portions. In this type of pedicillariae, the jaws are also operated by adductor and abductor muscles.

Pedicellariae are sensitive to contact and serve to caputure small prey. They also remove debris and minute organisms such as various larvae, sponges and coelenterates which settle on body surface and disturb the respiration by covering the dermal branchiae and tube feet.

BODY WALL

The body wall of *Asterias* is made up of epidermis, dermis, muscular coat and coelomic epithelium.

1. *Epidermis.* It is continued over all the external appendages. It is composed of ciliated columnar epithelium. The epithelium secretes outside itself a thin two-layered citucle. Scattered in the epidermis are few gland cells and neurosensory cells. The gland cells are of two types (i) goblet or mucous gland cells which are filled with finely granular substances and provide the body surface with a protective mucous coating and (ii) muriform cells, which are filled with coarse spherules. Neurosensory cells are spindle shaped and are connected to nerve plexus or net situated below the epidermis.

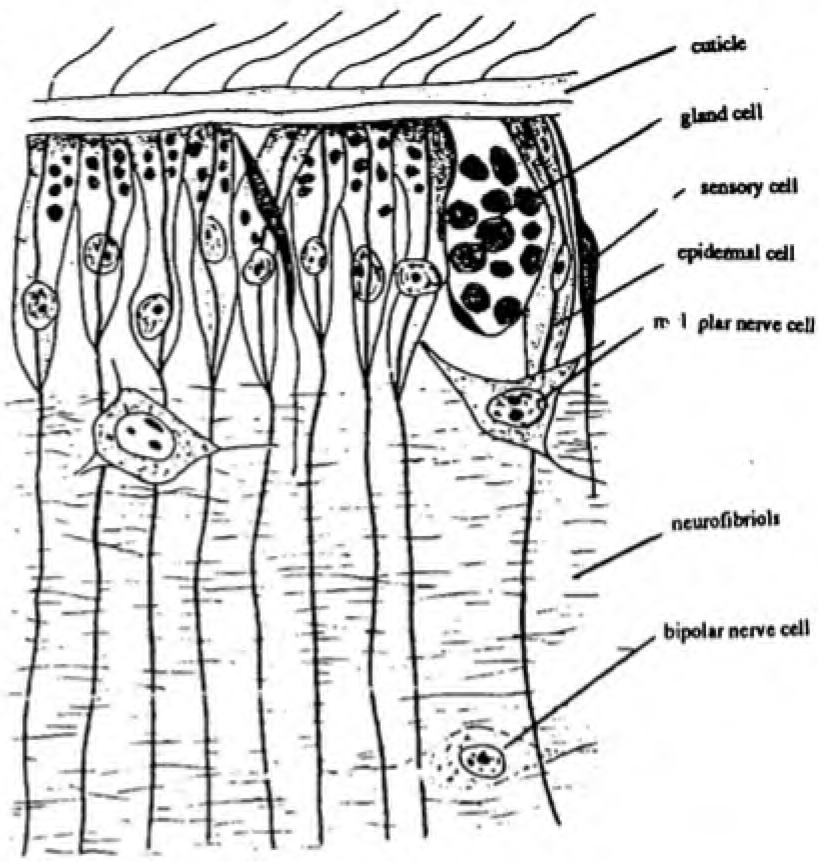


Fig. 67.6 *Asterias*. Section of body wall

2. *Dermis.* Below the epidermis is dermis which is separated from the former by a thin basement membrane. It is formed of fibrous connective tissue and can be divided into two regions (i) the outer and (ii) inner. In the outer region, there are self- secreted calcareous plates or ossicles which form the hard endoskeleton. It is to be specially noted that in other invertebrates the endoskeleton is ectodermal in origin (if present) where as in *Asterias* it is mesodermal. The inner region of the dermis consists of smooth or involuntary muscle fibres. It is differentiated into an outer circular muscle layer and an inner longitudinal muscle layer. The longitudinal muscle is thicker and better developed on the aboral side than the oral side and brings about bending of the arms.

4. *Coelomic epithelium.* The inner most layer of the body wall is the parietal coelomic epithelium, consisting of ciliated epithelium.

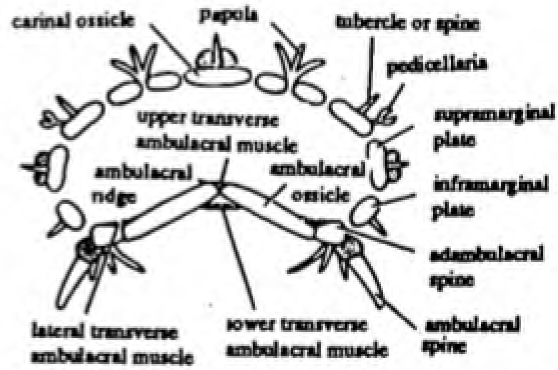


Fig. 67.7 A cross section through an arm of sea star to show endoskeleton

Enoloskeleton

The rigidity of body of *Asterias* is due to the presence of definite skeleton. As already stated, the endoskeleton consists of rod-like calcareous ossicles are of various shapes and are bound together by connective tissue. They form a reticulate skeleton, leaving spaces for the emergence of groups of papulae. The endoskeleton has a crystalline calcite structure. The flexibility of the body results from the fact that the ossicles are not united into an entirely rigid covering, but remain distinct and bound together by connective tissue and muscle that is why movements are possible.

On the aboral side the ossides are irregular but on the sides of the ambulacral groove they lie in two rows which meet together at the apex of the groove like the rafter supporting the roof of a shed and forming a conspicuous ambulacral ridge. These ossicles are elongated and are called the *ambulacral ossicles.* The two rows of the ambulacral ossicles can be approximated and separated to close or open the ambulacral groove. The ambulacral ossicles do not bear any spines, tubercles or other external appendages. The two notches of the adjacent ossicles together form an oval aperture, the ambulacral pore, for the passage of a tube-foot. The ambulacral pores are so arranged that they form two rows on each side of the ambulacral groove. At its outer end, each ambulacral

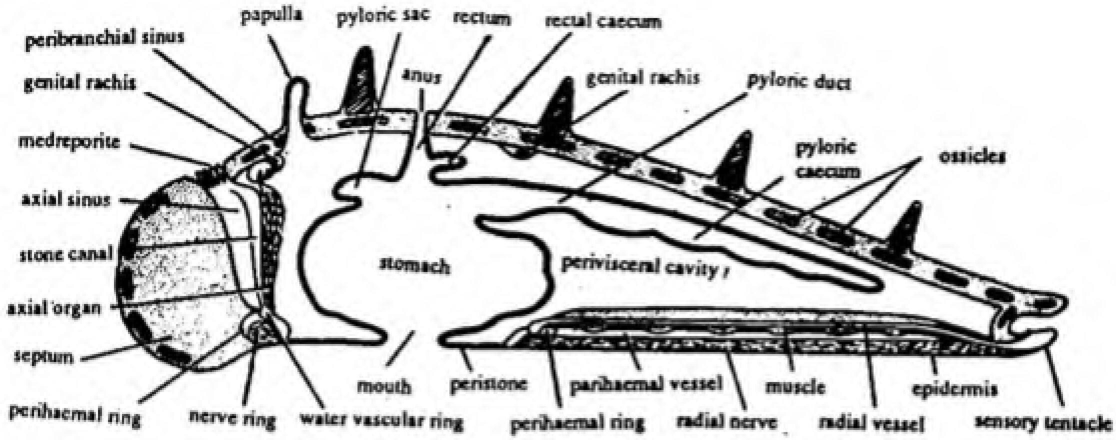


Fig. 67.8 *Asterias*. Diagramatic V.S. of disc and an arm.

groove articulates with one *adambulacral ossicle* forming the edge of the groove and bearing two or three movable spines on small tubercles. Next to the adambulacral ossicle there are two rows of the ossicles called *supra* and *inframarginal ossicles*.

Coelom

The coelom is present in the form of a large cavity situated below the body wall and extends into the arms. It is lined by ciliated epithelium. There is a large perivisceral coelom extending into the central disc and the rays and surrounding the visceral organs. Besides, there are also a number of other coelomic compartments such as the water vascular system, axial sinus, perihaemal canals and sinuses, and the genital sinuses etc. There are spaces in the dermis which are without definit linings and, therefore, not regarded of true coelomic origin. The coelomic epithelium is not only applied to the inner surface of the body wall as parietal layer but also invest the visceral organs as visceral layer.

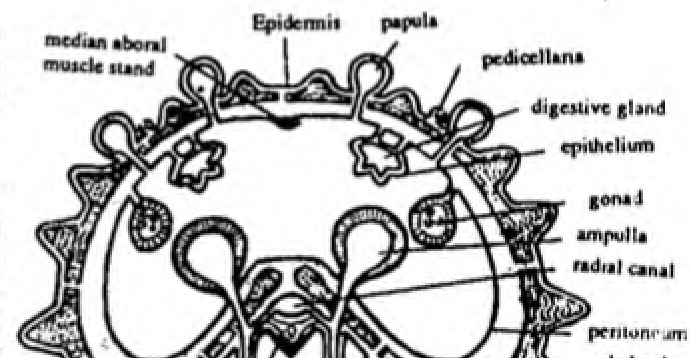


Fig. 67.9 *Asterias*. T.S. of an arm

The coelom is filled with coelomic fluid containing amoeboid corpuscles. The composition of this fluid is like that of sea water. The coelomic fluid, like haemolymph of arthropods, serves to bathe the tissue in the absence of true blood. The cilia of coelomic epithelium serve for transportation of materials between various parts of the body. The amoeocytes collect the excretory substances which, when collected in sufficient quantity, is expelled out through some papillae. The amoebocytes also act as phagocytes for removing harmful foreign substances. Some coelomocytes have respiratory pigment. Oxygen is taken into the coelomic fluid and carbon dioxide eleminated into the surrounding sea-water through the thin walls of skin gills.

DIGESTIVE SYSTEM

The digestive system consists of alimentary canal and digestive glands.

I. Alimentary canal.

The alimentary canal is complete extending from oral to abroal side. Therefore, it is very short and wide at places. It comprises mouth, oesophagus, stomach, intestine and anus.

1. ***Mouth.*** The mouth is the anterior most aperture of alimentary canal and it is situated in the centre of the peristomial membrane on the oral surface. It is provided with a sphincter muscle and radial fibres and is capable of great expansion and retraction.

The mouth leads upward into the oesophagus.

2. ***Oesopnagus.*** The mouth leads into oesophagus which is a short and wide. It extends ventrally and open into the stomach.

3. ***Stomach.*** The stomach is a broad sac and fills the interior of the disc. It is typically divided by a horizontal constriction into a voluminous oral part, the cardiac stomach and a flattened aboral part the pyloric stomach.

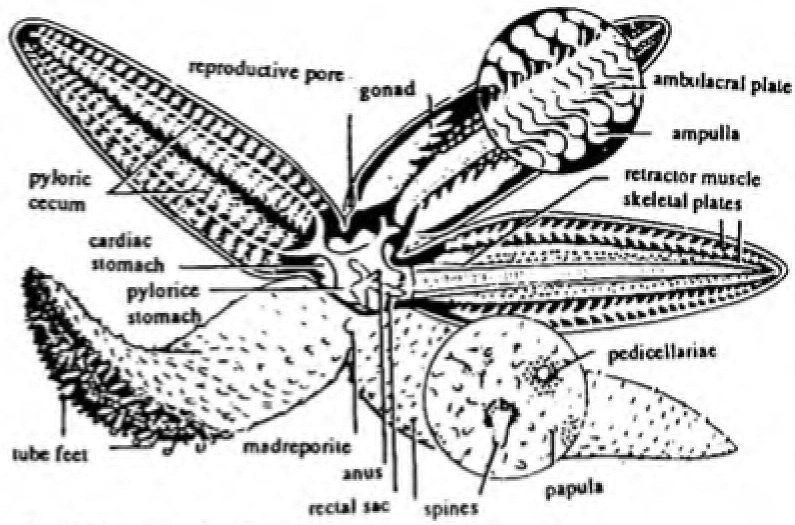


Fig. 67.10 *Asterias*. Showing anatomy.

   (a) *Cardiac stomach.* It is the larger oval part connected with the oesophagus. its wall is thin and greatly folded. The cardiac stomach is held in position by five pairs of mesenteries or retractor muscles or the gastric filaments which are formed of connective tissue and muscles. A pair of gastric ligaments connect the cardiac stomach to the ambulacral ridge in each arm. The stomach is capable of everting out through mouth by the action of muscles extending from the body wall.

   (b) *Pyloric stomach.* It is a small, flat pentagonal sac opening aborally into the intestine. The angles of the pentagon lie along the radii and each receives a duct, called the pyloric duct, from the corresponding pyloric caeca or digestive glands.

4. ***Intestine.*** It is a short, narrow five sided tube which is continued to the aboral surface where it opens into the anus. It gives out at interradial position two or three small branched and brownish appendages called the intestinal or rectal caeca. The intestinal caeca secrete a kind of brownish fluid which is supposed to be excretory in function.

5. ***Anus.*** The anus is a very small opening on the aboral surface somewhat eccentrically located.

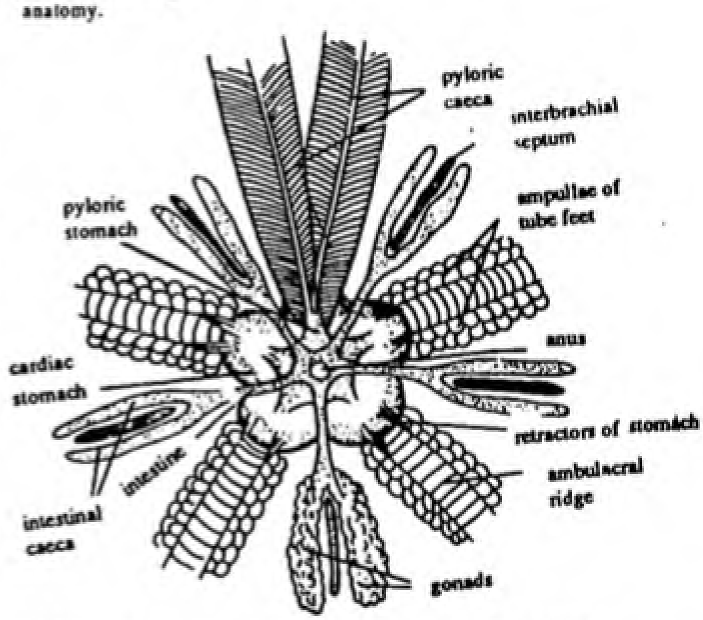


Fig. 67.11 *Asterias*. Showing digestive and reproductive systems.

II. Digestive glands.

The digestive glands of *Asterias* are five pairs of digestive glands or pyloric caeca which are long, brownish or greenish in colour. Each arm of sea star contains a pair of digestive glands or pyloric caeca extending up to its tip, and each is suspended from the aboral body wall by a pair of longitudinal mesenteries.

The hollow axes of the two pyloric caeca of an arm open into a common pyloric duct which opens into the pyloric stomach at one of its angles.

The pyloric caeca are lined by ciliated columnar epithelium having four types of cells:

(i) *Secretary or granular cells* which produce proteolytic, amylolytic and lipolytic enzymes.

(ii) *Mucous cells* which secrete mucus.

(iii) *Storage cells* which store reserve foods as lipids, glycogen and protein-polysaccharide complex.

(iv) *Current producing cells* which bear longer flagella that maintain a steady flow of enzymes towards the stomach along the aboral side and of digested food into the pyloric caeca along the oral side.

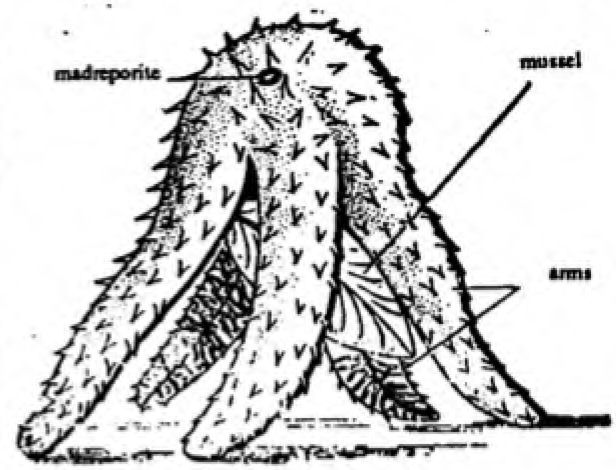


Fig. 67.12 *Asterias*. Feeding on a mussel.

FOOD

The *Asterias* are carnivorous and feed upon all sorts of invertebrates, especially snails, bivalves, crustaceans, polychaetes, other echinoderms and even fishes. They also consume the bodies of dead animals encountered on the bottom.

Feeding mechanism, Digestion and Absorption. In some sea-stars, the prey is swallowed whole and digested within the stomach, although the stomach wall must be in contact with the tissues being digested. Shell and other indigestible materials are then eleminated out of the mouth. In *Asterias* through the contraction of the body wall muscles, the coelomic fluid exerts pressure on the cardiac stomach, causing it to be everted through the mouth. The everted stomach, which is anchored by gastric ligaments, engulfs the prey. The prey then may be brought into the stomach by retraction, or digestion may begin outside the body. The digested food in then passed into the body in ciliated gutters. When digestion is completed, the stomach muscles contract, retracting the stomach into the interior of the disc. The clams are devoured in an interesting manner. During feeding the sea star extends itself over a clam, holding the gape of the clam upward against the mouth and applying the arms against the sides of the clam valves. The sea star inserts the everted stomach through minute openings between the imperfectly sealed edges of the valves. The gape is produced quite rapidly and not by causing the clam to fatigue over a long period. The everted stomach pours out powerful proteolytic enzymes which completely dissolve the soft viscera of clam. The cilia of stomach set up strong currents that carry the digested food into the stomach and then pyloric caeca. By the contraction of muscles the everted stomach is withdrawn into the interior of the disc.

Thus the digestion is extracellular. Some intracellular digestion is believed to take place in pyloric caeca. The food is chiefly absorbed in pyloric caeca, which also store the food material. Distribution of food of various parts of the body takes place through the coelomic fluid. The undigested materials are eleminated mainly through the mouth. Little, if any, egestion takes place through the anus.

WATER VASCULAR SYSTEM OR AMBULACRAL SYSTEM

The ambulacral system is derived from the coelom, from which it separates during development of the animal. It can be distinguished into following parts:

1. Madreporite
2. Stone canal
3. Ring canal
4. Tiedmann's bodies
5. Polian vesicle
6. Radial canal
7. Transverse canal
8. Tube feet

1. **Madreporite.** The madreporite is a light coloured, sieve like, circular skeletal plate present inter-radially on the aboral surface of the disc. Its surface is marked by a number of radiating narrow, straight or slightly wavy grooves or furrows which provide it a characteristic appearance. Each furrow is furnished with minute pores which open into a sac-like ampulla through minute pore canals. The number of pores may be 250. The ampulla leads into a S-shaped stone canal or madreporic canal.

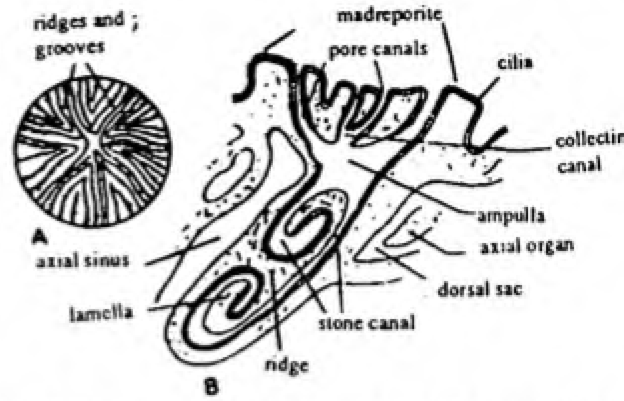


Fig. 67.13 *Asterias* A—Madreporite seen from outside. B—V.S. through madreporite.

2. **Stone canal.** The ampulla opens into a S-shaped stone canal. The stone canal extends downwards and opens into a ring canal, around the mouth. The walls of stone canal is supported by a series of calcareous rings. The lumen of stone canal is lined by very tall flagellated cells. In embryonic stages and in young *Asterias*, the stone canal remains a simple tube but in adult, lumen of stone canal possesses a prominent ridge with two spirally rolled lamellae which by branching become more complicated in structure. During its course, the stone canal along with axial organ is ensheathed by a wide, thin-walled tubular coelomic sac, called axial sinus. The three together called *axial complex*.

3. **Ring canal.** It is a wide, somewhat pentagonal canal forming a ring around the oesophagus. The angles of pentagon are situated in the radial position.

4. **Tiedmann's bodies or Racemose glands.** These are small rounded yellow, glandular sacs which open into a ring canal on its inner side, between each radius and interradius except where stone canal opens into the ring canal, there is one Tiedmann's body. Thus there are in all nine Tiedmann's bodies. Each consists of a peritoneum enclosing a stroma of connective tissue and muscle fibres having many radiating tubules. Recently, studies with the electron microscope pointed out that each cell of radiating tubules has flagellum in the midst of microvilli-like processes. The function of Tiedmann's bodies is not yet known. However, it is believed that they serve for filteration or as enzyme forming structure or lymphatic glands which produce phagocytic amoebocytes to be set free in the water vascular system.

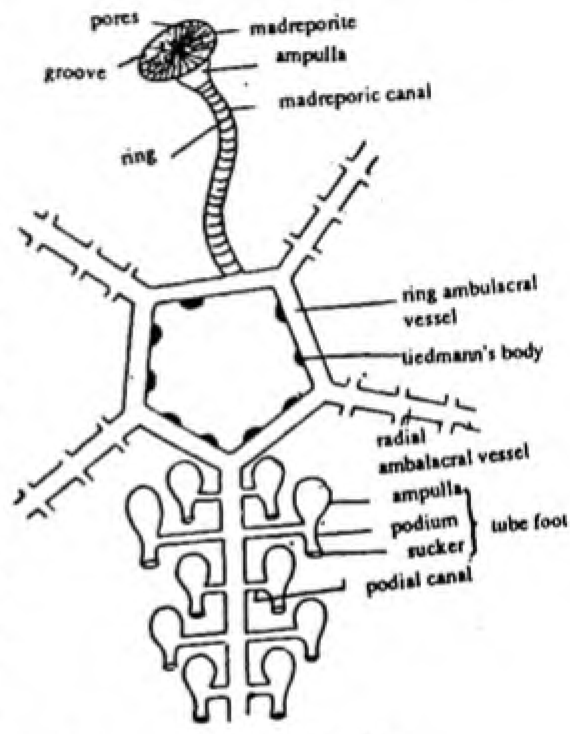


Fig. 67.14 *Asterias*. Ambulacral system.

5. **Polian vesicle.** In most sea-stars, but not in Asterias, the ring canal gives off in each interradius one, two or even four large, thin-walled, pear-shaped sacs known as polian vesicles. They are contractile structures and perform several functions. According to some workers they serve as central organs for regulating pressure in the ambulacral system. According to others they are some sort of lymphatic glands which give rise to amoebocytes of the ambulacral system.

6. **Radial canals.** From the outer surface of the ring canal are given out 5 radial canals, one to each arm upto its extremity through the ambulacral groove of the arm. Each runs passing above the radial nerve and terminating in the lumen of the terminal tentacle.

7. **Lateral canal.** In each arm, the radial canal gives out two series of short, narrow, transverse branches called lateral or podial canals. Each lateral canal is attached to the base of a tube foot and is provided with a valve to prevent backward flow of fluid in the radial canal.

8. **Tube feet.** There are two double rows of tube feet in each arm, one double row in relation to each series of alternately placed

long and short lateral canals. Each tube foot has the form of a closed thin-walled tube. It extends through a gap, called the *ambulacral pore*, which lies between two adjacent ambulacral ossicles. Each tube foot can be distinguished into three regions:

(i) *Ampulla*. It is a rounded sac-like structure situated above the ambulacral ossicles and projecting into the coelom.

(ii) *Podium*. It is a median tubular part which extends through the ambulacral groove.

(iii) *Sucker*. It is a cup-like structure situated at the lower end of podium.

The tube feet have strong longitudinal muscles.

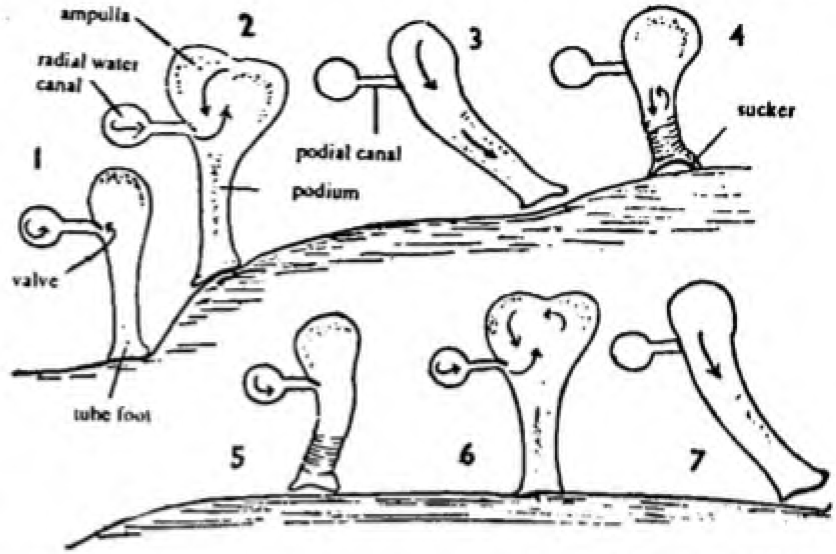


Fig. 67.15 *Locomotion* in a star-fish. 1. water enters the radial canal, 2. water fills the ampla, 3. podium swings forwards. 4. podium contracts and vaccum is created below the sucker. 5. sucker is released and podium is pulled back, 6. water fills the ampulla as before, and 7. podium swings forward to catch the substratum.

The various parts of ambulacral system have a muscular wall lined internally by ciliated epithelium covered, according to their position, by epidermis or coelomic epithelium.

The whole system is filled with a watery fluid which is identical to the sea water. Water enters through the pores of madreporite and circulates through the system by the action of cilia.

Functions. The ambulacral system chiefly helps in locomotion. It also helps in food cepture and attachment of substratum.

LOCOMOTION

In sea star, there is no head or anterior end. It can move in any direction and any arm can take the lead for locomotion. Locomotion is achieved with the help of water-vascular system which maintains a hydraulic pressure. The beating of cilia of the water vascular system causes the sea water to enter through the madreporite. After passing through the stone canal, ring canal, radial canals and lateral canals, it reaches the tube feet and their ampullae.

Locomotion in a horizontal surface. When the sea star desires to move on horizontal surface, the tube feet push the body forwards. The ampullae of raised arms contract, the valve in the podial canal close and the water of ampullae is forced into the podia. The podia elongate in the general direction of movement due to hydrostatic pressure products by the influx of water into them.

The terminal suckers of the tube feet are brought in

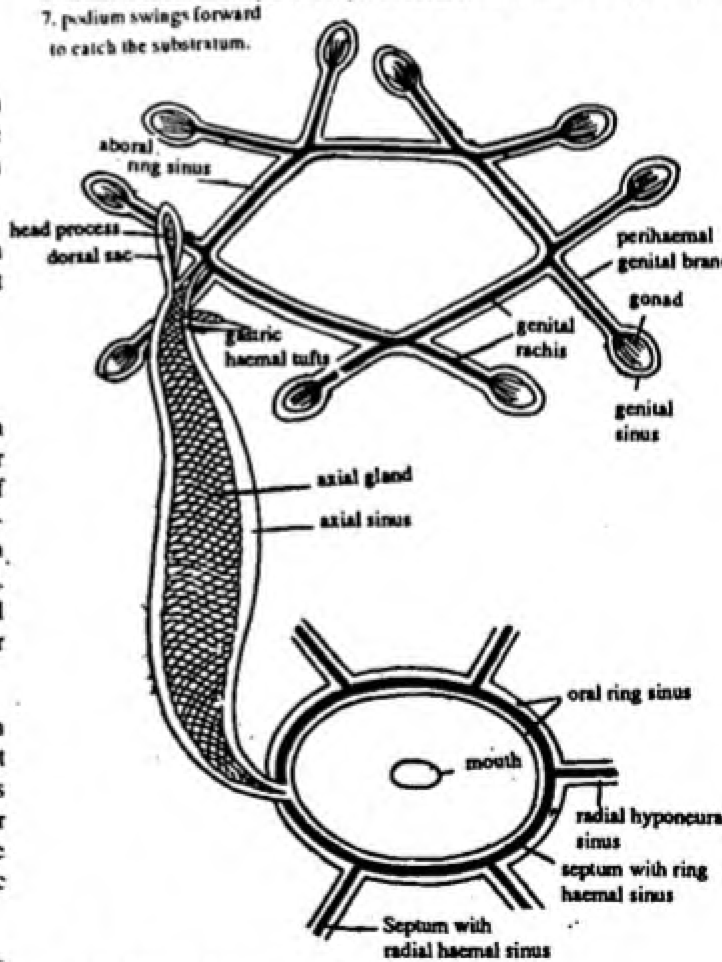


Fig. 67.16 *Asterias*. Perihaemal and haemal system.

contact with the substratum and their central parts are withdrawn to form suction cups. The adhession is further strengthened by mucous secreted by the tips of tube feet. The tube-feet now pivot forward on their attached suckers, assuming vertical position and thereby pushing the body forward. The tube-feet then shorten by contracting their longitudinal muscles and forcing some water back into their ampullae and releases their suckers. The ampullae then contract again and whole sequence of events is repeated.

Locomotion on a vertical surface. In climbing a vertical surface, the tube-feet pull the body forwards. By the alternate contraction and expansion of tube-feet and by adherance of suckers of tube-feet on surface *Astarias* climbs on the vertical surface.

The tube-feet, however, may or may not work in coordinated manner. As a result, the *Asterias* moves forward steadily but slowly, at a speed of 15 cm per minute. The tube-feet are employed when the substratum is hard. On soft mud or sand the suckers of tube feet become useless. On such surface the animal walks on its extended tube feet which now act like small legs.

CIRCULATORY SYSTEM

A true blood vascular system is absent. The system responsible for circulation of digested food to various organs of body is often termed as circulatory system. It is made up of two parts.

I Perihaemal System

II Haemal System

I. The perihaemal system. It is also derived from the coelom and is lined with cuboidal ciliated epithelium. It comprises:

1. Axial sinus
2. Aboral ring sinus
3. Genital sinuses
4. Oral ring sinus
5. Radial perihaemal sinuses
6. Marginal sinuses
7. Peribranchial sinuses

1. *Axial sinus.* It is a wide, nearly vertical, thin-walled tube surrounding the stone canal and the axial gland. At its aboral end it communicates with the ampulla of stone canal and also with the exterior by some of the pore canals of the madreporite. At the same end, it opens into the aboral ring sinus. The three (stone canal, axial gland and axial sinus) together form an axial complex.
2. *Aboral ring sinus.* It is a pentagonal channel lying around the intestine, just beneath the central disc. It does not make a full circuit as it is incomplete in the region of the stone canal. It gives off 10 genital branches, two in each inter-radius. The aboral ring sinus and its genital branches contain genital rachis, a continuation of the axial gland.
3. *Genital sinuses.* Each gonad is surrounded by a small genital sinus which is connected with the aboral ring sinus by a short and slender branch.
4. *Oral ring sinus.* At its oral end, the axial sinus opens into the inner division of a circular channel, the oral ring sinus or peribuccal or hyponeural perihaemal ring sinus surrounding the mouth. It is a large tubular sinus and internally divided by an oblique septum (the haemal strand) into two-a smaller inner ring and a larger outer ring. From the outer part of the oral ring sinus arises five radial perihaemal sinuses.
5. *Radial perihaemal sinuses.* 5 such sinuses arise from oral ring sinus. Each one extends through each arm between the radial nerve and the radial ambulacral vessel. The radial sinuses are also divided by radial septa into two each. The radial perihaemal sinuses also give out fine channels into the tube feet.

6. *Marginal sinuses.* In each arm, two longitudinal marginal sinuses run longitudinally on each side just aboral to the marginal nerve cord. The fine lateral channels connect the marginal channels with the radial perihaemal sinuses.
7. *Perihaemal sinuses.* These are small spaces in the dermis of the body wall. These communicated with the radial hyponeural sinuses of the arms.

II. Haemal System. The haemal or blood lacunar system is much reduced in *Asterias* and is open type like the haemocoel of Arthropoda and Mollusca. It is derived from the blastocoel. The system consists of intercommunicating spaces which have no epithelial lining. These are enclosed in the coelomic spaces of perirhaemal system. The channels are filled with coelomic fluid containing coelomocytes. Histologically, the system is bounded by a layer of connective tissue, externally covered by coelomic epithelium. The haemal system comprises:

1. Axial haemal ring
2. Aboral haemal ring
3. Oral haemal ring
4. Radial haemal sinuses.

1. *Axial gland.* It is also known as *heart* or *brown gland* and forms the principle part of the haemal system. It has an external lining of peritoneum and its interior is filled with connective tissue containing many small inter-communicating spaces filled with a fluid with amoeboid coelomocytes with a brown pigment. The axial gland is connected with the oral haemal sinus at its oral end and with aboral haemal sinus at its aboral end. A small terminal head process arises from the aboral end of the axial gland. It communicates with a small dorsal sac in the madreporite. A pair of gastric tufts arising from the haemal sinuses in the wall of cardiac stomach open into the axial gland near its aboral end. The food digested in the stomach enters the haemal circulation through the gastric tufts.
2. *Aboral haemal ring.* The axial gland, at its aboral end connects with the ampulla of madreporic canal and joins a pentagonal ring canal situated beneath the aboral surface of the central disc. From this canal, five pairs of genital haemal strands are extended to gonads. These haemal strands are two in each inter- radius.
3. *Oral haemal ring.* It is the circular haemal sinus, located around the mouth just below the ring canal of the water vascular system.
4. *Radial haemal sinuses.* From the oral haemal ring arise five radial haemal sinuses or strands. One of these runs out through the septum of each hyponeural radial sinus. The radial haemal branches give out from their sides short branches to tube feet.

RESPIRATION

In *Asterias*, respiration takes place by the dermal branchiae or papulae scattered over the aboral surface and by the tube feet projecting in the ambulacral groove. Both the respiratory structures are thin walled and are continuous with coelom. Oxygen dissolved in sea water diffuses into coelomic fluid through these structures. The coelomic fluid distributes oxygen to all internal tissue and brings carbon dioxide to the respiratory organs for outward diffusion.

EXCRETORY SYSTEM

These is no distinct excretory system in echinoderms. It is likely that there may be some organ in connection with the ambulacral system or with the axial sinus for excretion. The nitrogenous metabolic excretory waste usually contains ammonium compounds. The excretion is brought about with the agency of coelomocytes that pick up wastes and pass them out through the papullae. The rectal caecae serve in excretion to some extent. There is certain amount of diffusion of dissolved water through the gills and thin wall of tube-feet.

NERVOUS SYSTEM

The nervous system of *Asterias* is of simple and primitive type. It is confined to the body wall. It consists of four parts:

1. Superficial or Ectoneural or Epidermal nervous system

2. Deeper hyponeural

3. Aboral or Coelomic nervous system

4. Visceral nervous system

1. **Superficial or Ectodermal nervous system.** This nervous system is situated just beneath the epidermis. It is the main part of sensory nervous system. It includes circumoral nerve ring, radial nerve cords and subepidermal nerve plexus.

   (i) *Circum oral nerve ring.* The nerve ring is pentagonal in shape and is circum-oral i.e., occurs around the mouth in the peristomial membrane. It supplies nerve fibres to the peristomial membrane and the oesophagus and at each radius gives off a radial nerve.

   (ii) *Radial nerve cords.* The radial nerve cords arise from the angles of the nerve pentagon and extend outwards, one through each arm. Each radial nerve terminates as a sensory cushion on the aboral side of the terminal tentacle. Each nerve cord is 'V' shaped in cross-section and continuous on its outer side with the epidermis. It remains separated on its inner side from the hyponeural sinus only by a thin dermis and the coelomic epithelium.

   (iii) *Subepidermal nerve-plexus.* It is in the form of an extensive network of nerve cells and nerve fibres situated below the epidermis all over the body surface including the papulae, pedicillariae and spines. In each nerve cord it is joined to radial nerve cord by five nerve fibres. In each nerve cord it forms a pair of marginal nerves out of which one traverses along each margin of the ambulacral groove and forms a nerve ring in the sucker of each tube feet.

The nerve pentagon and radial nerves contain many neurons, arranged in sensory, association and motor tracts. They receive and coordinate responses similar to that of central nervous system found in other animals.

2. **Deeper nervous system.** It is situated on the oral side just beneath the perihaemal sinuses and a little above the epidermal nervous system by a thin layer of connective tissue. It consists of a double nerve pentagon running round the mouth and sending a double radial nerves or Lange's nerve in each arm. Each nerve is continued as a plate of nervous tissue in the outer oral wall of the radial hyponeural sinus and gives out branches to the muscles of the arm. The deep nervous system originates from the mesoderm. Its function is primarily motor.

3. **Aboral or Coelomic nervous system.** It is represented by a thin nerve plexus situated in the aboral body wall, just above the parietal layer of coelomic epithelium. It is somewhat thickened to form an anal nerve ring in the central disc and a nerve in each arm. The aboral nervous system is connected with the marginal nerves by several lateral nerves in each arm. This system is also mesodermal in origin and motor in nature.

4. **Visceral nervous system.** It is situated in the gut wall just outside the enteric epithelium. It has the form of a conspicuous plexus which has connections with the visceral receptors and also with the muscles layers of gut wall.

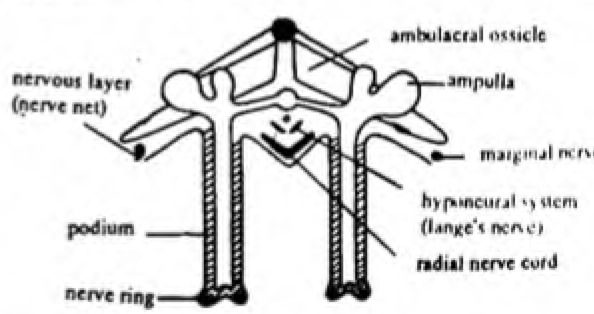


Fig. 67.17 *Asterias.* Nervous system in section.

SENSE ORGANS

The sense organs of *Asterias* are of three types:

1. Neurosensory cells

2. Eyes

3. Terminal tentacles

1. **Neurosensory cells.** These are present here and there in epidermis. They are more or less spindle shaped containing the nucleus, a distal thread-like process reaching to the cuticle, and a proximal fibre entering the subepidermal nerve plexus.

They may act as tectile receptor or chaemoreceptors. They are especially numerous in the suckers of podia, at the base of spines, pedicillaria and terminal tentacles.

2. **Eyes.** The eyes are small, bright-red spots, one under the base of the terminal tentacle of each arm. Each eye is also called optic cushion as it is really a special thickening of radial nerve. Each eye comprises a number of cup-shaped concavities lined by alternating pigmented cells and retinal cells. The pigment cells contain an orange pigment. The retinal cells are elongated cells with a distal bulbous enlargement projecting into the cavity of the cup and a proximal fibre passing into the underlying radial nerve. The number of ocelli in one eye ranges from 80-200 in different species. Each concavity is covered by a transparent cuticle and may contain a lens beneath the cuticle and may contain a lens beneath the cuticle. The lens is formed by epidermis. Eyes are sensitive to light and detect change in the intensity of light.

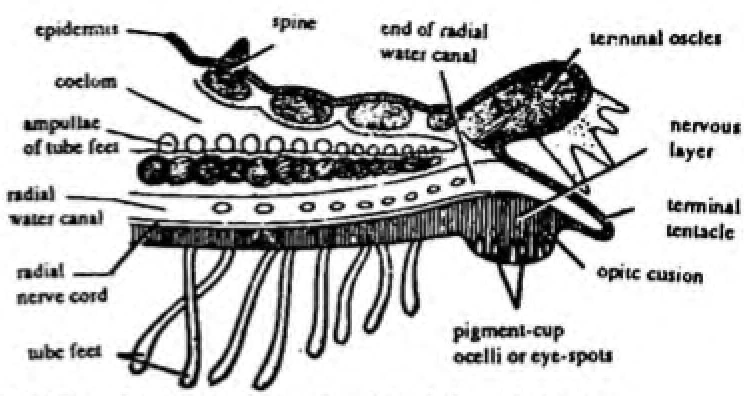


Fig. 67.18 *Asterias*. L.S. of an arm through terminal tentacle showing position of eye.

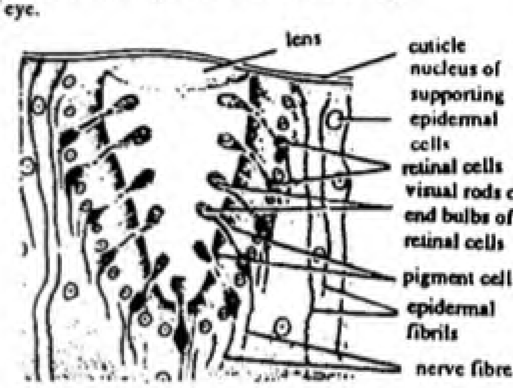


Fig. 67.19 *Asterias*. V.S. through an eye pit.

3. **Terminal tentacles.** The terminal tentacles have sensory cells which are tactile and also sensitive to food.

REPRODUCTIVE SYSTEM

Asterias is unisexual i.e. dioecious. The male and female are separate but both the types of gonads are morphologically alike and situated in similar positions. They have only microscopic differences. The reproductive system is simple. Ovaries and testes consist of small rounded follicles like the bunches of grapes. They, however, differ in colour. The testes are pale-grey while ovaries from pink to orange. There are five pairs of gonads in either sex, a pair in each interradius. The gonads are attached at the bases of the arms and extend freely into the proximal parts of the arms on the sides of pyloric caeca. From the proximal end of each gonad arises a short dilated gonoduct which opens out laterally on the aboral surface by a minute gonopore. There are no special organs for copulation. The accessory glands and recepticles are also absent.

The sex-cells are believed to originate in the aboral part of the axial or from the wall of coelom near the proximal part of the axial gland and then migrate through the genital rachis to the gonads.

There is a single breeding season in sea-stars i.e. late spring. The ripe ova and sperms are simply shed into the sea water where fertilization takes place. Maturation and shedding of gametes are controlled by a secretion of neuro-secretory cells in radial canal (*Chaet* and *McConnangly*, 1959). According to *Binyon* (1964), the axial organ may serve as a chaemoreceptor for substances received through the madreporite, thus stimulating the release of gametes. A single female lays about 200 million eggs in a season.

Fertilization. It is external and takes place in the sea water.

After fertilization the zygote divides into two equal blastomeses, the cleavage is holoblastic. Cleavage

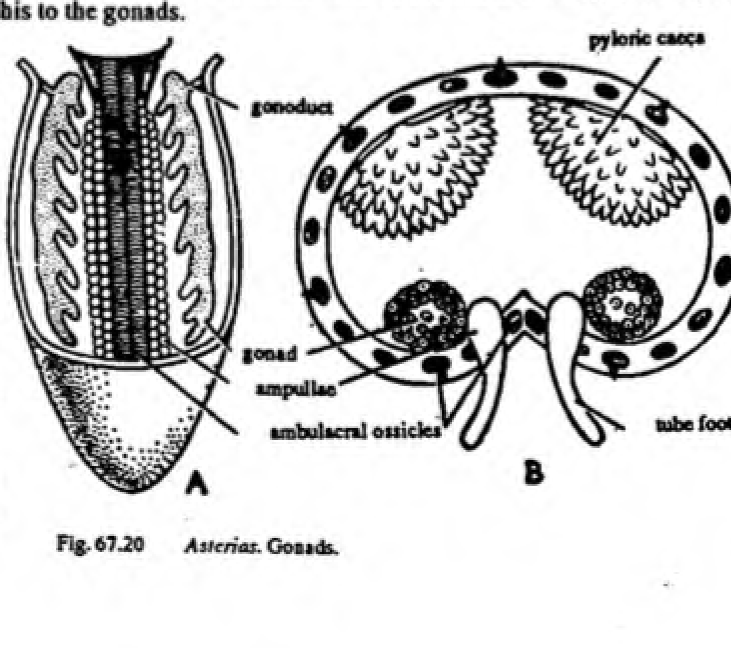


Fig. 67.20 *Asterias*. Gonads.

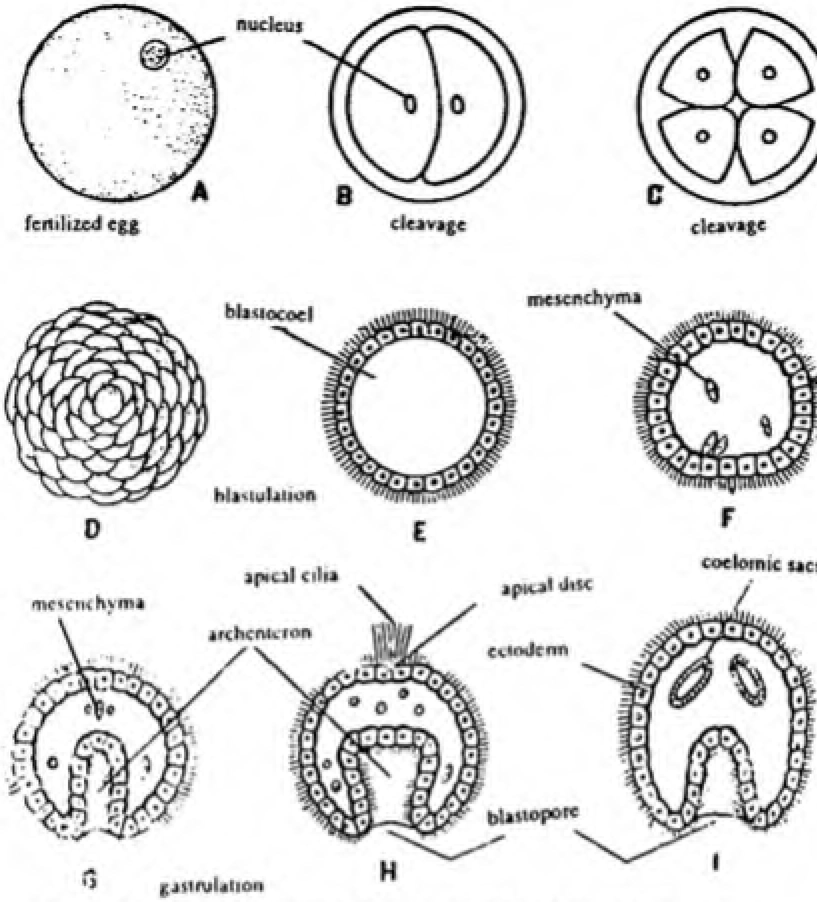


Fig. 67.21 *Asterias*—Stages in the development. (A) Unfertilized eg, (B) Two cell stages, (C) Four cell stage, (D) Biastula (E) Biastula in section, (F) Early gastrula, (G) Formation of mesenchym. (H) Older grastula, (I) Formation of coelomic sacs.

leads to the formation of blastula by second day. The blastula sooner or later develops a blastocoel and is called *coeloblastula*. After a free swimming existence of about a day the blastula undergoes embolic invagination and becomes a two layered, cup-like gastrula. Its outer layer is formed of ectoderm and inner layer of endoderm. The cavity of gastrula which is lined by endoderm is known as archenteron. It opens to the exterior by a wide aperture called blastopore. The *archenteron*, formed as a result of gastrulation, is narrow. When fully formed it gives rise to a coelomic sac, the hydroenterocoel, on each side. The two occupy the right and left of the archenteron and gradually elongate anteriorly in the plan of the long axis of the larva. From the left hydro-enterocoel arises a dorsal evagination which forms the water pore. Ventrally a stomodaeal inpushing is formed. This meets the archenteron and completes the digestive tract. The blastopore forms the anus. Now the alimentary canal is differentiated into oesophagus, stomach and intestine along with mouth and anus. The two hydroenterocoels continue to develop anteriorly where they fuse to form a U-shaped coelom. Finally the posterior parts of U are cut off from anterior axocoels forming right and left somatocoels. The uniform ciliation of the body is replaced by two ciliary wavy bands-a *perioral band* surrounding the mouth and an *aboral band* lying inside the mouth. With these changes embryo develops into *dipleurula larva* capable of independent existence. It actively feeds on diatoms etc. The aboral band of cilia helps in collecting the food particles. The larva swims near the surface

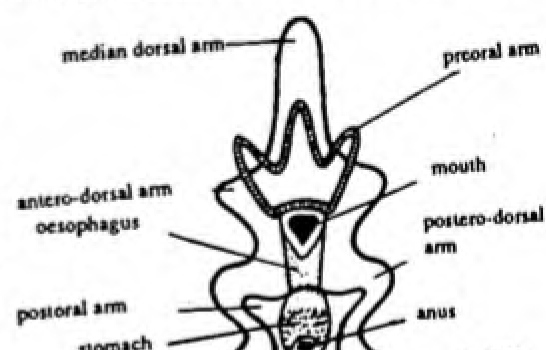


Fig. 67.22 A *bipinnaria larva*.

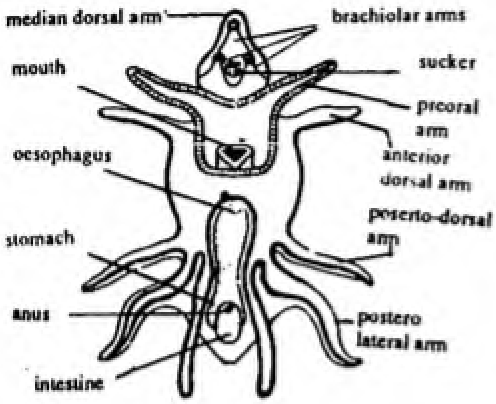


Fig. 67.23 *Brachiolaria larva.*

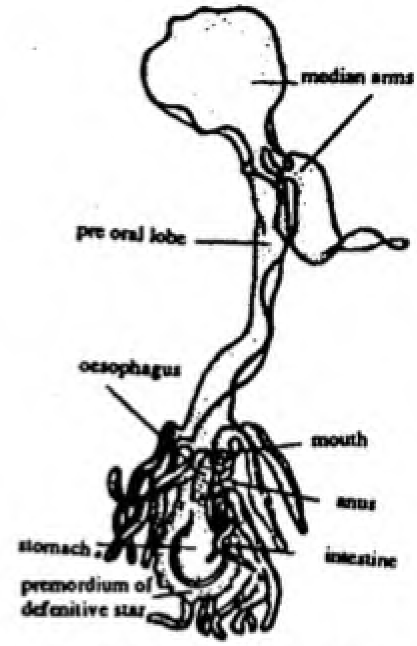


Fig. 67.24 *Metamorphosis in larva.*

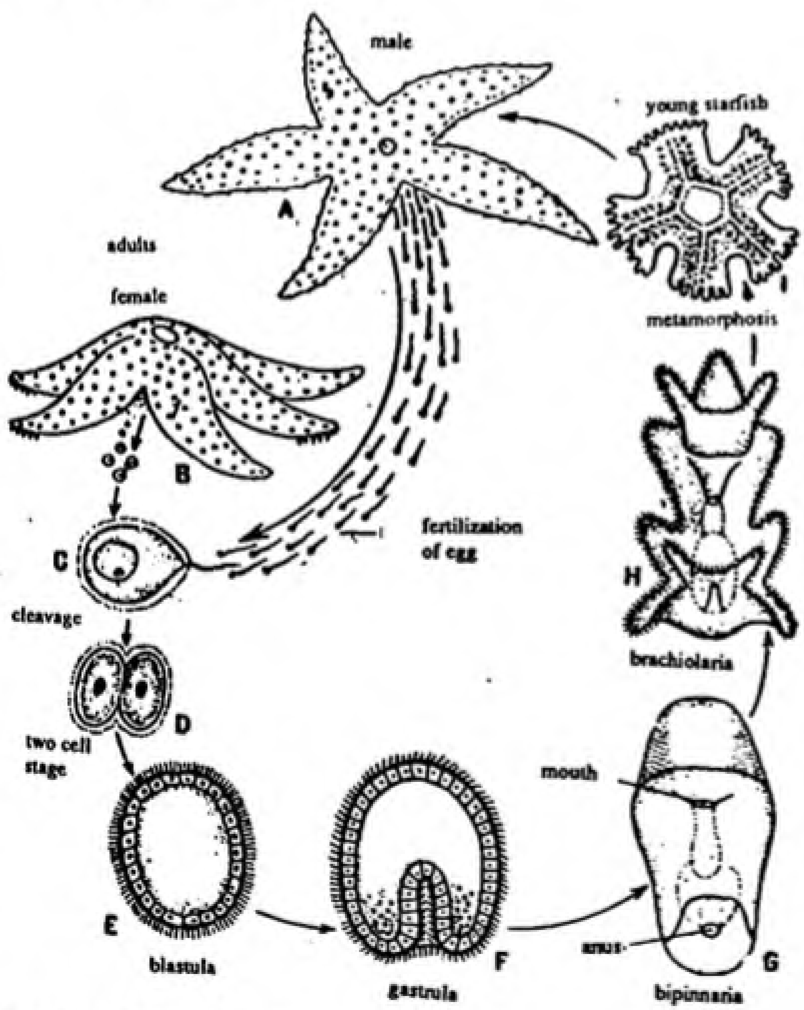


Fig. 67.25 *Asterias.* Life history.

and rotates clock-wise with the help of peri-oral band of cilia.

Bipinnaria Larva. The dipleurula larva forms on its front side a big preoral lobe, which is bordered by a preoral loop made up of cilia. Soon three lateral lobes are formed and these lobes are also bordered by a postoral loop of cilia. The larva is now called bipinnaria. It is also bilaterally symmetrical. It swims and feeds independently. After some weeks it is transformed into the next larva known as *brachiolaria larva.*

Brachiolaria larva. The lobes of bipinnaria larva become modified into long, slender, ciliated and contractile larval arms. From the preoral lobe arise three short and non-ciliated processes ending into suckers. These processes are called fixing processes. This is now known as branchiolaria larva. It swims and feeds like bipinnaria larva.

METAMORPHOSIS

The bilaterally symmetrical larva gradually metamorphoses into the radially symmetrical adult. After about 6 or 7 weeks the brachiolaria settles down on some solid object or to the bottom, where it remains temporarily attached by its fixing processes. The anterior end of the larva degenerates and forms only an attachment stalk, and the adult body develops from the rounded

posterior end of the larva. The left side becomes the oral surface and the right side becomes aboral. The adult arms apper as extensions of the body. Internally the entire digestive tract degenerate. All these parts formed anew and in a position coinci ing with the adult radial symmetry. The left axohyrocoel forms the water-vascular system and from the hydrocoel develop five pairs of projections, two in each of the developing arms. These projections represent the cavity and coelomic lining of first pair of podia in each arms. As about this time, the skeletal system appears. The first adult ossicles to be formed are those around the aboral pole, which contains the anus. New ossicles are then added peripherally to the initial skeleton. The detached young sea star is not more than 1 mm in diameter.

68

WATER VASCULAR SYSTEM IN ECHINODERMATA

The water vascular system or ambulacral system is peculiar to Echinodermata and not met within any other groups in the Animal Kingdom. Since the entire system is derived from the coelom the system is lined with a ciliated epithelium and filled with a watery fluid and contain corpulces. This system is used for locomotion. It probably functions in collecting and distribution of food. The ambulacral system consists of madreporite, stone canel, ring canel, radial canal, and tube feet. The system is variously modified in different classes of Echinodermata.

CLASS - I ASTEROIDEA

Asteroids ambulacral system follows the general echinoderm pattern with certain modifications.

Madreporite. It is a light coloured, sieve-like, circular skeletal plate present inter-radially on the aboral surface of the disc. Its surface is marked by a number of radiating narrow, straight or slightly wavy grooves or furrows. Each furrow is furnished with minute pores which open into a sac-like ampulla through minute pore canals. The number of pores may be 250. The ampulla leads into a 's' shiped stone canal.

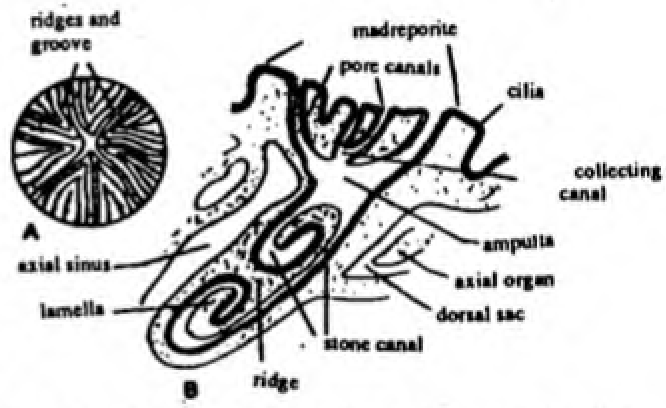


Fig. 68.1 *Asterias*. A—Madreporite seen from outside, B—V.S. through madreporite.

Stone canal. The stone canal extends downwards and opens into a ring canal, around the mouth. The walls of stone canal is supported by a series of calcarious rings. The lumen of stone canal is lined by very tall flagellated cells. The lumenn of the stone canal is divided by a longitudinal ridge. In *Asterias* the ridge is bifurcated. In *Asteropecten*, the ridge meets the opposite wall and the interior is divided into tubes which are provided with a pair of scrolls each.

Ring canal. It is a wide, somewhat pentagonal canal forming a ring around the oesphagus. The angles of pentagon are situated in the radial position.

Tiedmann's bodies. These are smell rounded yellow glandular sacs which open into a ring canal on its inner side, between each radius and interradius except where stone canal opens into the ring canal, there is one Tiedmann's body. Thus there are 9 Tiedmann's bodies. The function of these bodies is not yet known, probably they help in the formation of amoebocytes (coelomic corpuscles).

Polian Vesicle. In most sea-stars, but not in *Asterias*, the ring canal gives off in each interradius, one, two or even four large, thin walled pear-shaped sacs known as polian vesicles. They are contractile structures and perform several functions such as formation of coelomic corpuscles, regulation of pressure etc.

Radial canal. From the outer surface of ring canal are given out 5 radial canal, one in each arm upto extremity through the ambulacral groove of the arms.

Lateral Canals. In each arm, the radial canal gives out two series of short, narrow, transverse lateral canals each leads to a tube foot. They have valves.

Tube feet. Each tube foot is a hollow, elastic thin walled closed cylinder. It consists an ampulla, a tube a sucker. The tube feet are capable of greater extension and when extended they come out through ambulacral grooves.

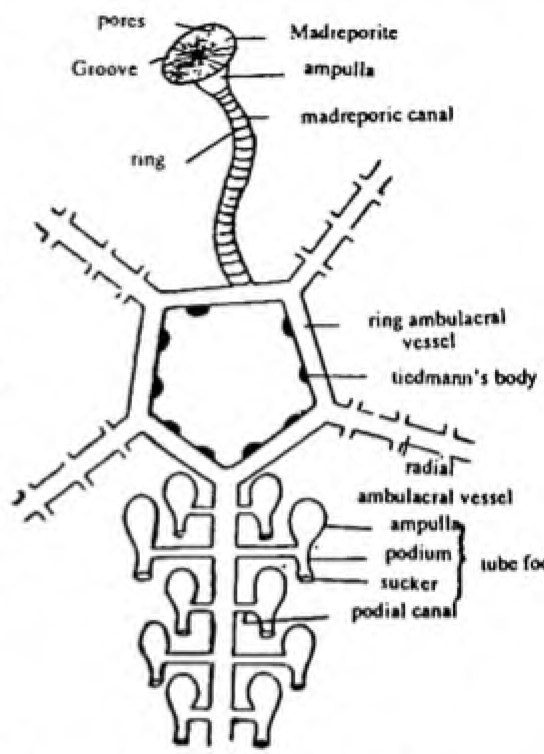


Fig. 68.2 *Asterias.* Ambulacral system.

CLASS - II OPHIUROIDEA

The water vascular system of Ophiuroidea has the same pattern like that of Asteridea. The oral shield that forms the madreporite usually bears but a single pore canal. In addition to the oral position of the madreporite, the stone canal ascends to the ring canal. The water ring canal bears four polian vesicles. Some times polian vesicles are accompanied by long slender, tabular appendages known as Simroth's appendages. Tiedmann's bodies are lacking. The ring canal gives a radial canal in each radius. It descends towards the oral side where it enters the arm base, extending along the arm upto its tip and terminates into the lumen of terminal tentacle. In each ossicle, the radial canal gives rise to a pair of lateral canals, which may extend directly to the pair of ventro-lateral podia. Ampullae are absent, probably correlated with the reduction of the arm coelom. A valve is present between lateral canal and podium. The entire water vascular system is lined with a ciliated peritoneum.

CLASS - III ECHINOIDEA

The water vascular system of echinoides is essentially like that of asteroides. One of the genital plates around the periproct contains pore and pore canals and functions as madreporite. A stone canal desend orally to the ring canal. The ring canal lies above the peristome in hearturchin or just above the chewing apparatus in regular urchins and sand-dollars. The radial canal extends from the ring canal and run along the underside of ambulacral areas of the test. Five polian vesicles are given out from the ring canal. Five Tiedmann's bodies are also present.

Each radial canal terminates in a small ampulla called as terminal tentacle. The radial canal gives off alternately on both sides lateral canals to the bases of the ampullae. The canals connecting the ampullae and podia. Each tude foot consists of an ampulla, a stalk and a sucker. The suckers are highly developed and are provided with a system of muscles and supporting ossicles.

CLASS - IV HOLOTHUROIDEA

Although he ambulacral system is basically like that of other echinoderms but the madreporite in most species have lost connection with the body surface and in being unattached in the coelom. Pore and pore canals are present in madreporite. The madreporite hangs just beneath the base of pharynx and is connected to the ring canal. The ring canal encircle the pharynx and gives rise polian vesicles. The number of polian vesicles varies considerable, 1 in *Cucumaria*, 3-4 in *Thyone* or as many as 10 or even 50 in certain *Apodida.* From ring canal 5 radial canals pass upward to the inner side of the calcereous ring. Each radial canal gives off small canals to the tentacles. The radial canal reduces in diameter and after passing through a hole in circum- oesophageal calcareous ring, it runs backwards along the inner surface of ambulacral area. Here lateral canals supply the podia and their ampullae.

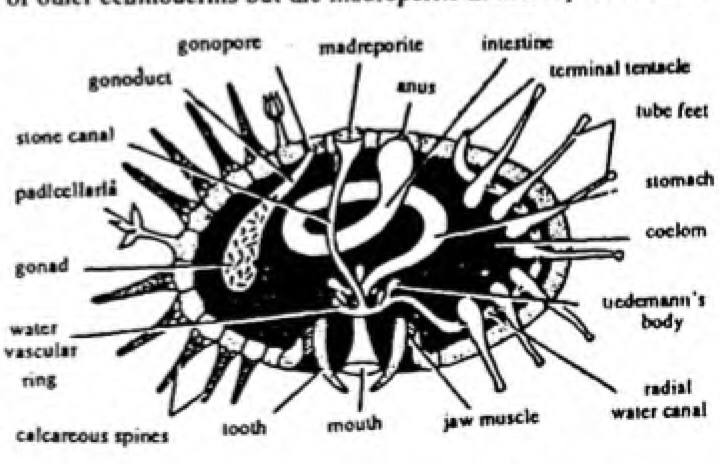


Fig. 68.3 Section of *sea urchin* to show *water vascular system.*

In the *Anodida*, the tube feet are absent hence the water vascular system is limited to the oral ring vessel, the polian vesicles and buccal tentacles.

CLASS - V CRINOIDEA

The madreporite is absent in crinoides. The ring canal encircles the mouth gives off at each inter-radius a large number of stone canal (30-50) which open into coelom. At each radus of ring canal, a radial canal extends into each arm just beneath the ambulacral groove and forks into all of the branches and into the pinnules. From the radial canals extend lateral canals supply the podia. There are no ampullae and one lateral canal supplies the group of three podia except in buccal region. Peculiar to crinoids are 500-1500 minute ciliated canals also called *ciliated funnels*. These funnels perforate the wall of tegmen and open into the underlying coelomic spaces. These openings compensate for the absence of madreporite, permitting sea water to enter the coelom and maintain a proper fluid pressure in the body and the water vascular system.

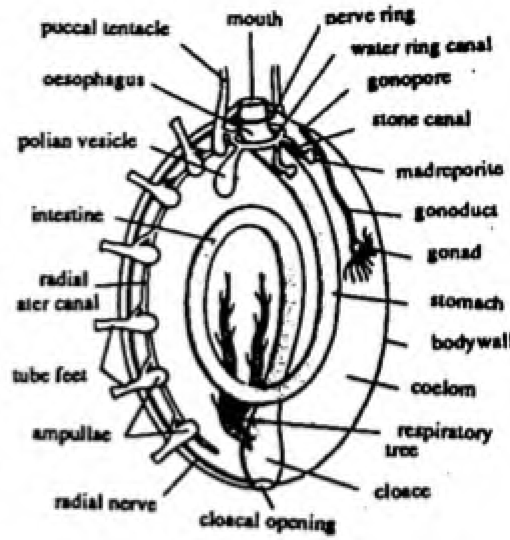


Fig. 68.4 Section of *Holothuria* to show water vascular system.

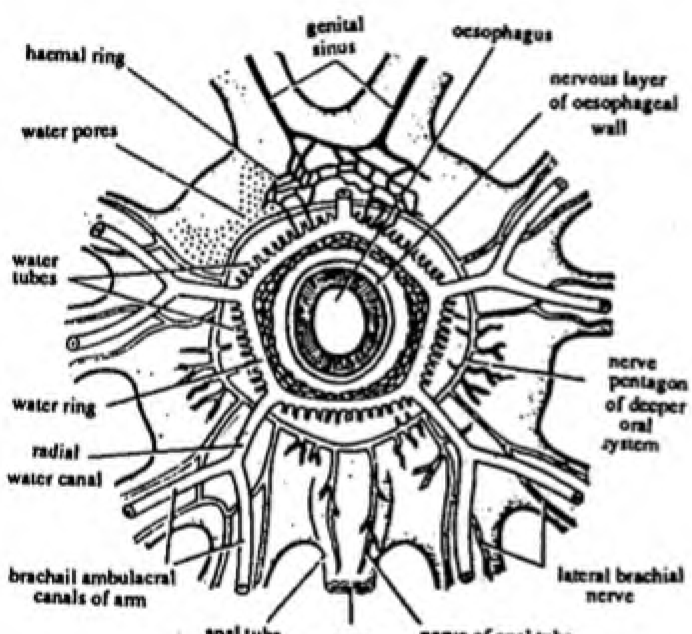


Fig. 68.5 *Antedon*. Showing water vascular system.

69

LARVAL FORMS IN ECHINODERMS

In echinoderms although the sexes are separate but there is no sexual dimorphism. The gametes are released directly in sea water where fertilization occurs. The development may be direct or indirect. In the direct development there is no larval stage but in the indirect development different kinds of free swimming larval forms are found. In each class, a few members, chiefly polar or deep - sea species, are viviparous. They rear the young in the brood opuch-like structure found in their body.

The most striking feature of the larva is its bilateral symmetry, which is in marked contrast to the radial symmetry of the adult. After a free-swimming life, the bilateral larva undergoes metamorphosis, in which the radial symmetry of adult is developed.

Class - 1 Asteroidea

Bipinnaria Larva. The egg hatches into a larva which develops the cilia and starts swimming freely. The alimentary canal is formed and larva feeds upon diatoms. In the wall of the gut, powerful ciliary band is present which helps in ingestion. Later the cilia of the body become restricted to the two cilary bands characteristic of Eleutherozoan larvae. The two lateral bands connect in front of the mouth as a pre-oral loop and infront of the anus as a pre-anal loop. The preoral loop later separates or in some cases develop independently into an anterior ciliated around the body. Three lateral lobes are formed on either side of the larva. The larva at this stage is called bipinnaria larva. Its development is completed between 2 - 7 days.

Internal development of bipinnaria . The tip of archenteron gives rise to the mesenchyme. The archenteron gives to a coelomic sac, the hydroenterocoel ,on each side. The two occupy the right and left of the archenteron and gradually elongates anteriorly in the plan of the long axis of the larva to form U-shaped coelom. The posterior ends of the lateral pouches become cut off from anterior axocoels and hydrocoels as right and left somatocoels. The left hydorcoel connects with the dorsal surface to form the hydropore without ectodermal invagination. On the ventral surface, the invaginated part of the ectoderm is connected with the endoderm. The alimantary canal of the larva can be divided into mouth, oesophagus,stomach, intestine and anus. The blastopore forms anus. At the time of metamorphosis, the right somatocoel and axohydrocoel are reduced while the left axocoel gives rise to water ring and radial canal. The axocoel separates from hydrocoel and contributes to stone canal. The madeporite is either formed by the rearrangement of the mesenchyme cells or by invaginated part of right axohydrocoel. After swimming for a few weeks the bipinnaria larva changes to next larval stage, the brachiolaria.

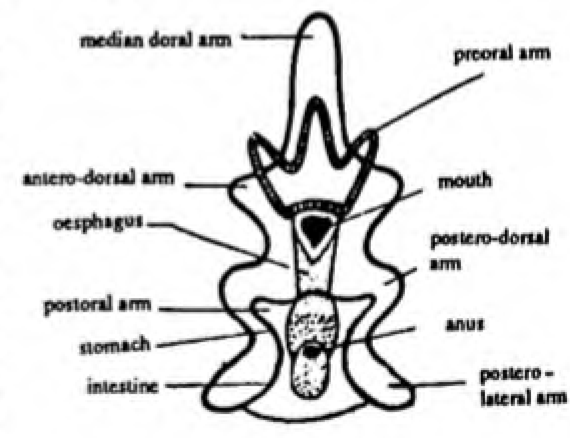


Fig. 69.1 *Bipinnaria larva.*

Branchiolaria larva. At the time of the changing of the bipinnaria into the branchiolaria, three additional arms are formed in the preooral lobe. These are called brachiolar arms of these one is median and two are laterals. These arms contain coelomic extension and adhesive cells at their tips. An adhesive glandualr region is found at their bases. It acts like a sucker. The appearance of sucker marks the beginning of metamorphosis.

Metamorphosis. The bilaterally symmetrical larva gradually metamorphoses into the radially symmetrical adult. After

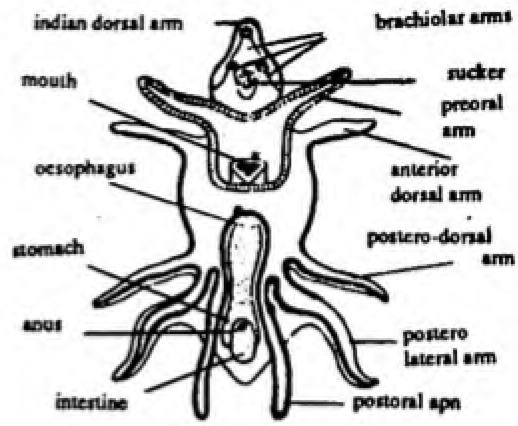


Fig. 69.2 *Branchiolaria larva.*

about 6 or 7 weeks the brachiolaria settles down on some solid object or to the bottom where it remains temporarily attached by its fixing processes. The anterior end of the larva degenerates and forms only an attachment stalk, and the adult body developes from the posterior end of the larva. The left side becomes the oral surface and right side aboral. The adult arms appear as extensions of the body. Internally the entire digestive tract degenerate. All these parts formed a new and in a position coinciding with the adult radial symmetry. The somatocoel forms the major part of coelom. The left axohydorcoal forms the water vascular system and from the hydrocoels develop five pairs of projections, two in each of the developing arms. These projections rrepresent the cavity and coelomic lining of first pair of podia in each arm. At about this time, sea star is not more than 1mm in diameter.

In some species, *Astropecten*, the development is shortened. Here the brachiolaria larva disappears and the bipinnaria larva metamorphoses into the adult after about three months. In *Asterina gibbosa*, the bipinnaria larva is not formed, the larva develops an adhesive apparatus, homologous to the brachiolar arms and sucker, which metamorphoses in adult. In *Luidia*, a giant and peculiar larva is formed known as *bipennaria asterigera.*

Class - 2 Echinoidea

Echinopluteus. In Echinoidea, a free swimming, microscopic echinopluteus larva is formed after gastrulation in about 7 - 30 days. The gastrula becomes somewhat cone-shaped and gradually develops into echinopluteus. The invaginated part of stomodaeum becomes connected with the archenteron and the gut is differentiated into mouth, oesophagus, stomach and intestine. The blastopore forms the anus. It bears six pairs of arms called preoral, anterio-lateral, anterio-dorsal post-oral, postero-dorsal and postero-lateral. The poster-lateral arms are very short and directed outwards or backwards. In some cases, the anteriodorsal arms may not develop. Thus there may be 5 or 4 pairs of arms in place of six pairs. The ends of these arms are pigmented and the skeleton is made up of calcareous rods, present in arms. These rods are originate from spicules secreted by mesenchyme. These rods may be thorny or simple or fenestrated or branched. The locomotion is performed by ciliated bands. In some cases the bands become thickened and known as epauletes. In *Arbacia and Cidaris*, the ciliated lobes are formed between the bases of the arms which are known as vibratile lobes auricular lobes or auricles.

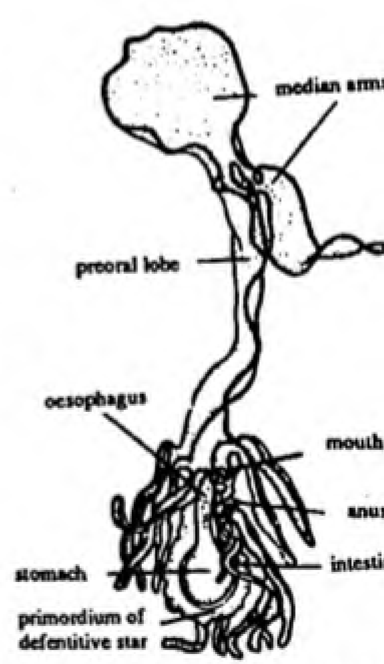


Fig. 69.3 *Larva showing metamorphosis.*

The archenteron gives off hydroenterocoels which continue to axocoel, hydrocoels, and somatocoels. The ectoderm formed and invagination on the left side which enlarges and forms a vestibule. The hydorcoel gives off five radial canals and give primary podia. The lantern of Aristotle is formed from left somatocoel.

Metamorphosis. The echinopluteus gradually sinks to the bottom. There is no attachment as in asteroids. Metamorphosis is rapid, taking place in about an hour. Internal development is basically like that of asteroids, although differing in detail. Young urchins are no longer then 1 mm.

Class - 3 Ophiuroidea

Ophiopluteus. The pluteus larva is also formed in the brittle stars and it is called ophiopluteus. It is similar to echinopluteus but the number of arms is less in ophiopluteus. Its posterio-lateral arms are formed first. The poserio-lateral, postoral and posterodorsal arms are developed respectively on 4th, 10th and 18th days. The ciliated bands accompany the arms edges. The coelomic chamber and archenteron are found in larva.

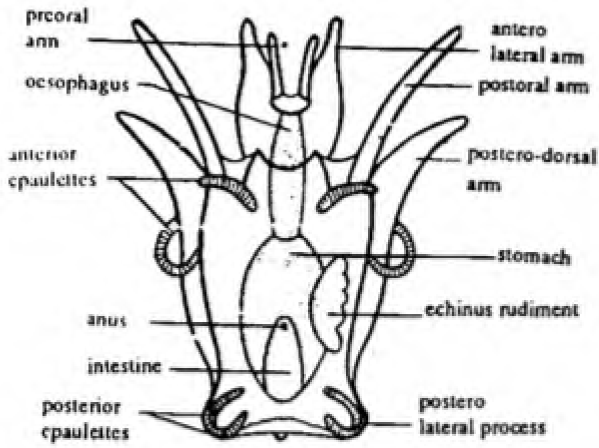


Fig. 69.4 *Echinopluteus larva.*

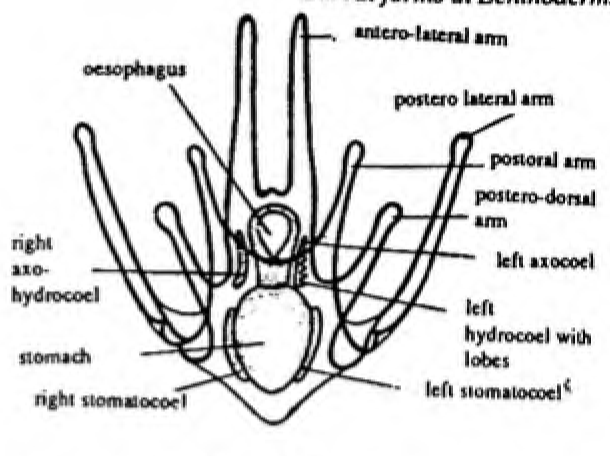


Fig. 69.5 *Ophipluteus larva.*

The internal development follows the same pattern as in other classes.

Metamorphosis. Metamorphosis starts after the appearence of the skeleton in larva. Metamorphosis takes place in free-swimming stage. In viviparous species like *Amphira viivpetra*, the pluteus stage is absent.

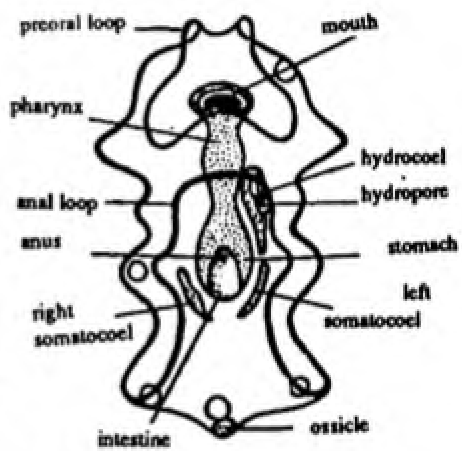


Fig. 69.6 *Auricularia larva.*

Class - 4 Holothuroidea

Auricularia. After the gastrulation and formation of coelomic sacs and gut, within three days a free swimming auricularia larva is formed. It is transparent and palegic in nature. It measures .5 to 1 mm in length. It swims with the help of ciliated bands. One of these bands encircling the mouth and is called pre-oral loop. Similarly, the ciliated band around the anal opening is called the anal loop. Internally, the larva contains a curved gut. The stomach is sacciform. Hydrocoel and the right and left somatocoels are also present. Lobes appear in the hydrocoel forming the primary tentacles which are connected with the hydropore by means of a duct. Some giant auricularia of unknown adults measuring 15 mm in length, have been reported from Bermuda, Japan and Canacy islands. They possess a frilly flagellated band.

Doliolaria. The auricularia larva soon changes into a barrel- shaped form, the doliolaria larva. In doliolaria stage, the continuous ciliated bands break to form 3-5 flagellated spheres. The mouth has shifted to the anterior pole and the anus to the posterior pole.

There are some species of holothuroids that possess a non-feeding barrel-shaped vitellaria. This type of larva, which is found in crinoid and a few ophuiroids, possess ciliated bands but no arms. In *Cucumeria planchi*, the auricular stage is ommited and the embryo directly develops into the doliolaria larva. In *Holotluria floridana* the embryo directly develops into young stage from the egg.

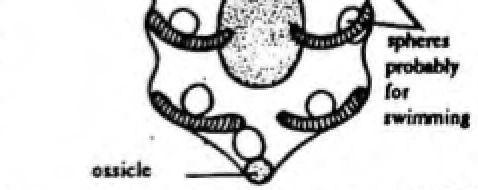


Fig. 69.7 *Auricularia to Doliolaria* (transitional stage).

Metamorphosis. Gradual metamorphosis, forming a young animal but with little loss of larval features, takes place during the latter part of planktonic existence. The tentacles, which are equivalent to buccal podia, appear prior to the appearance of the functional podia. At this stage, the metamorphosing animal is sometimes called **pentaculata larva**. Finally the young sea cucumber settles to the bottom and assumes the adult mode of existence.

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Doliolaria. After gastrulation and embryonic development of coelom and gut, the larva hatches as doliolaria larva. It is free swimming. An apical sensory plate, possessing a bunch of cilia is present as its anterior end. 4 or 5 ciliated bands are also present on its body. Near the apical plate in mid-ventral line the larva has an adhesive pit over the first ciliary band. The stomodeum or vestibule is present between 2nd and 3rd ciliated band. The skeleton also develops at this stage. The larva attaches itself to some object after the development of the prospective organs of the coelomic sac and its internal organs of the coelomic sac. Its internal organs rotate at an angle of 90° from the ventral to the posterior direction. The larva forms a stalk and at this stage it is known as the cystidean or pentacrinoid larva. After some time, it metamorphoses into an adult.

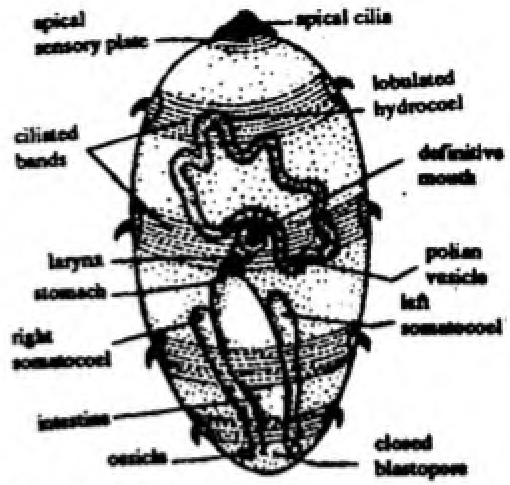

Fig. 69.8 *Doliolaria larva.*

SIGNIFICANCE

All the larval forms of echinoderms have a bilateral symmetry. Hence it is believed that the ancestor of enchinoderms was a bilaterally symmetrical animal. According to Semon (1888) the radial symmetry is secondary as the primary radial symmetry is seen in coelenterates and porifera. The adult echinoderms are more primitive than their larvae because the adults possess the characters of the lower animals like coelenterates etc. during metamorphosis the advanced larva becomes a primitive adult. Such a metamorphosis is called *retrogressive metamorphosis*.